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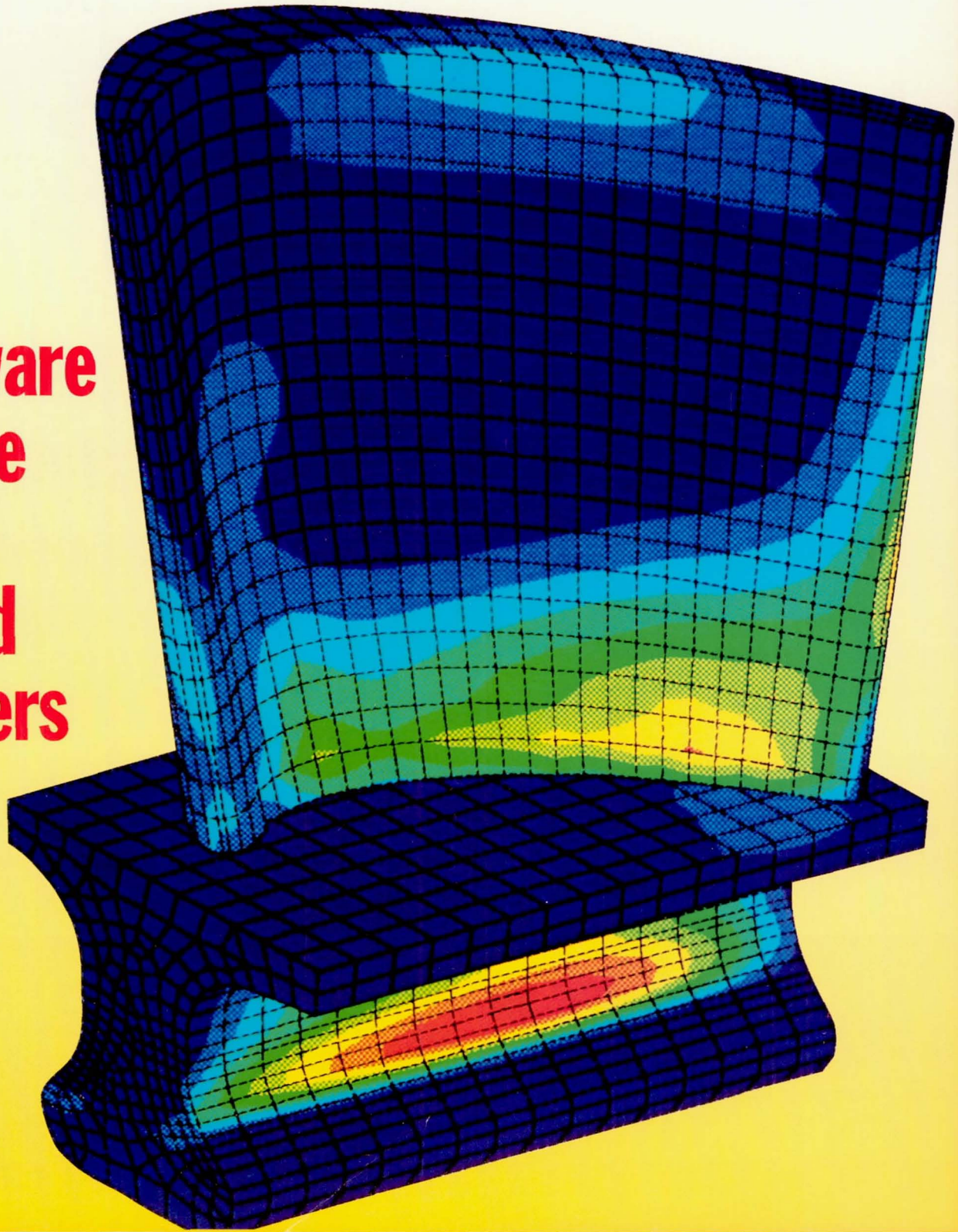

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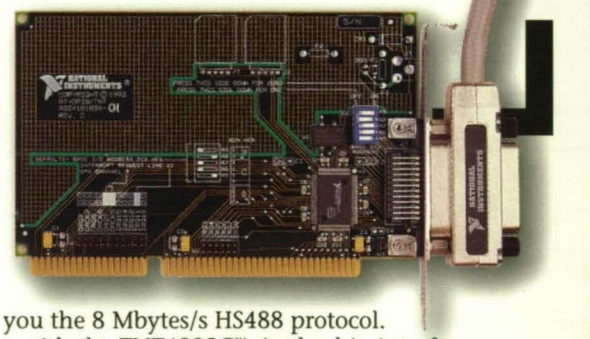

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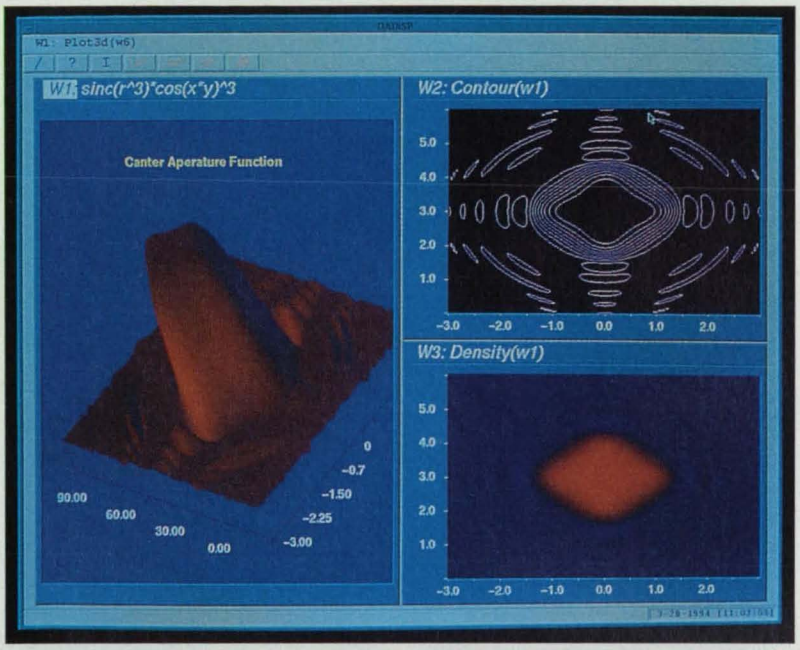

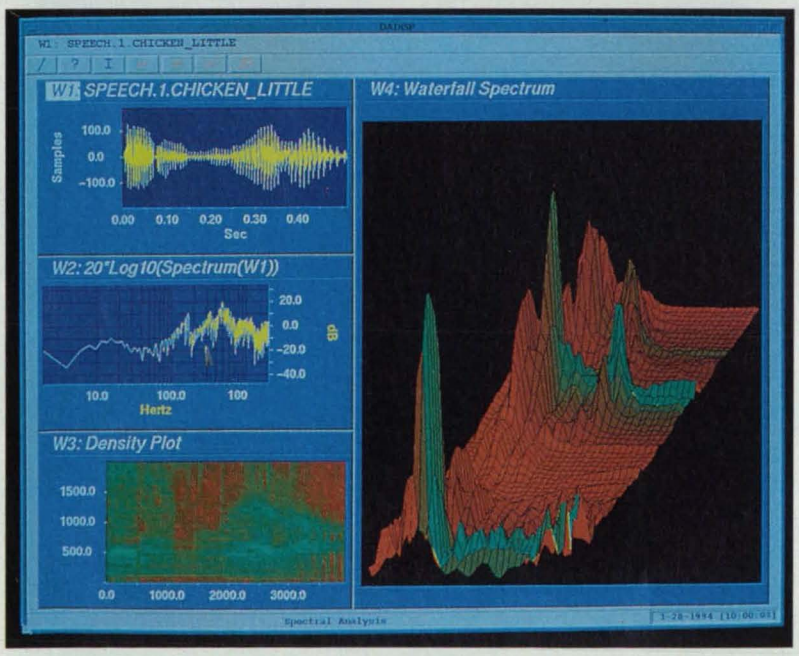

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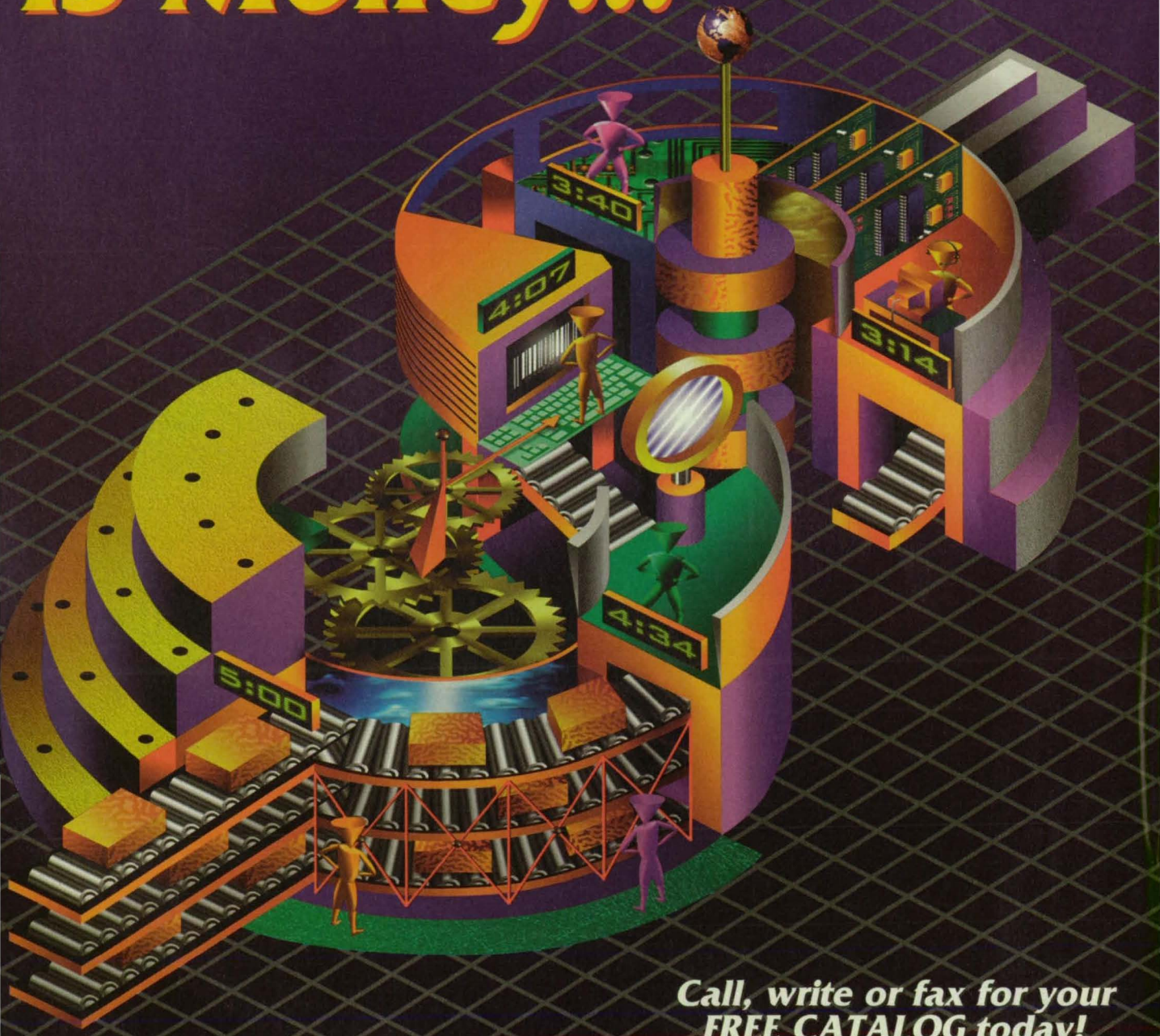

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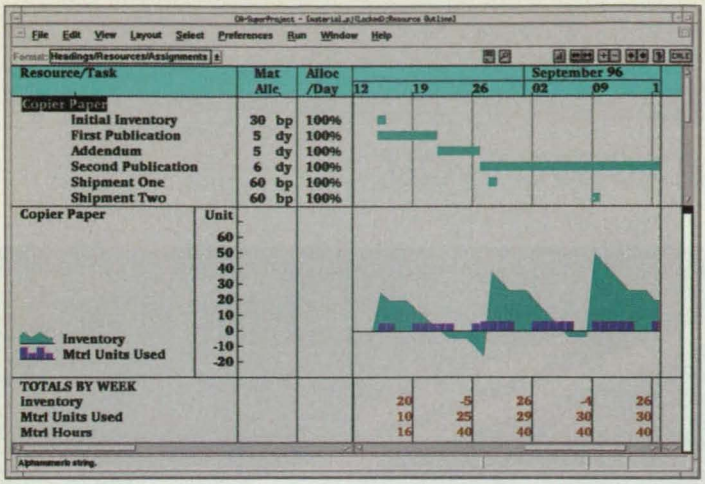
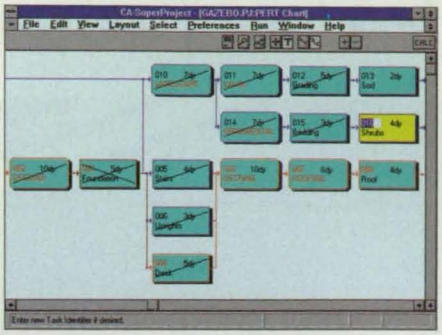
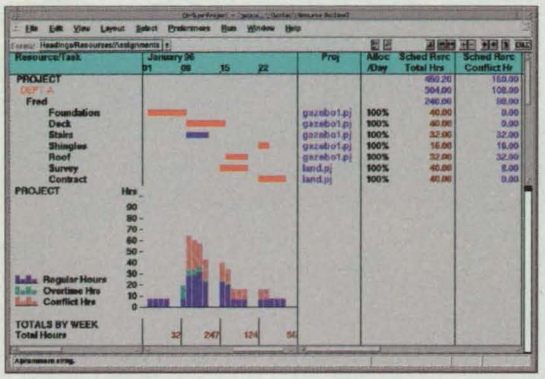


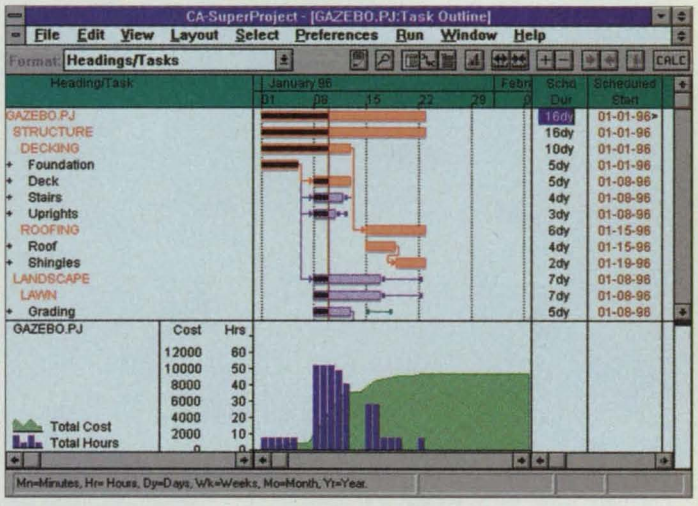
Track and manage the production, inventory and use of materials in addition to the management of labor, equipment and other resources.



Change project views to see WBS or PERT charts showing dependency links, milestones and status.



View project status quickly and easily to anticipate and avoid costly project delays.



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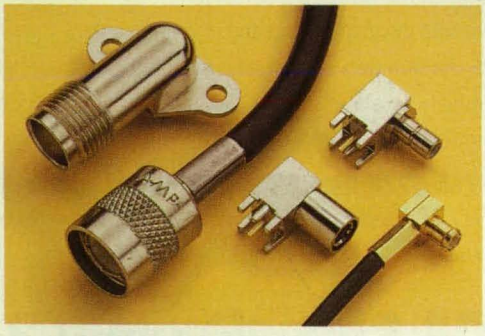

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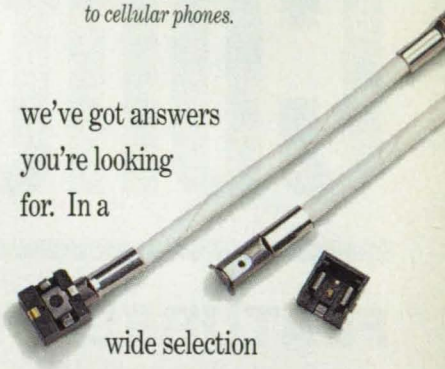
With its 4GHz top end, our latest RF addition is at home in a range of products, from instrumentation to cellular phones.



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TECHNICAL SECTION

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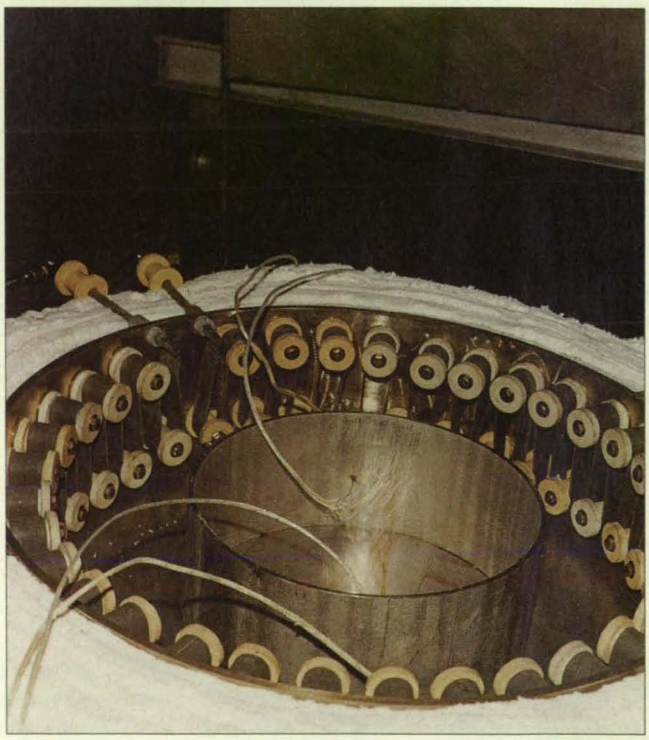

Engineers at Marshall Space Flight Center have designed electric preheaters to improve vacuum plasma spraying of large structures, which must be heated uniformly to the requisite high temperatures before the plasma torch arrives. The ring preheater shown above heats cylindrical stainless-steel barrels twelve inches in diameter in a 40-torr vacuum to 900 °C. See the tech brief on page 76.

Photo courtesy Marshall Space Flight Center

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Contents *(continued)*

DEPARTMENTS

On the cover:

CARES/LIFE, co-winner of the first annual NASA Software of the Year Award and developed at the Lewis Research Center, analyzes the reliability and predicts the lifetime of ceramic components in engines and other high-stress applications. This stress contour plot of a turbine rotor blade shows the probabilities of failure for all regions of the component and can assist engineers in designing for minimal failure.

Photo courtesy of Solar Turbines Inc.

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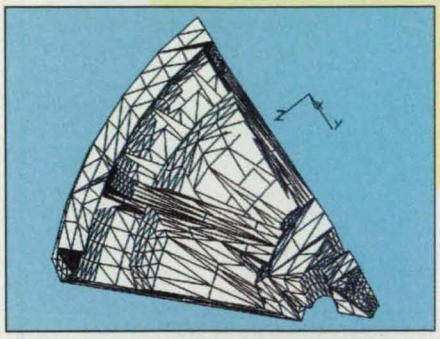
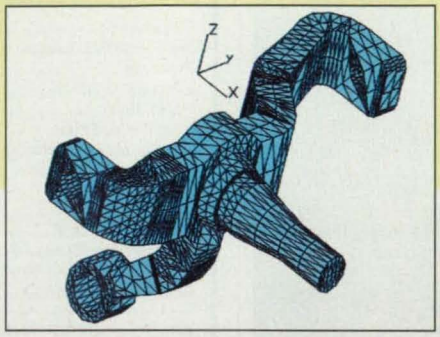
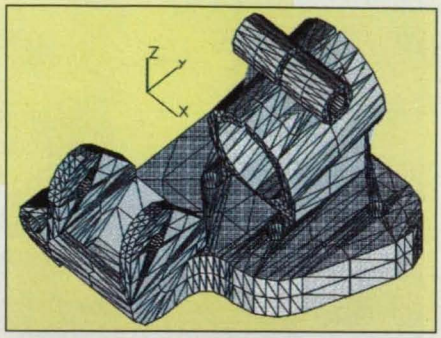
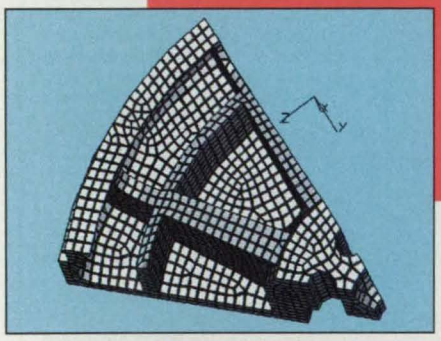
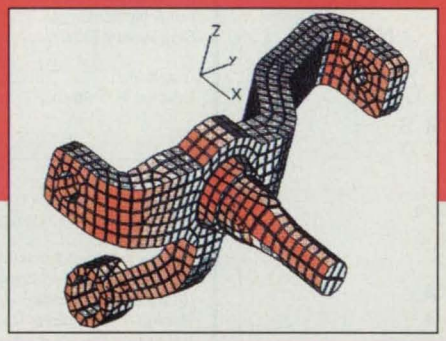


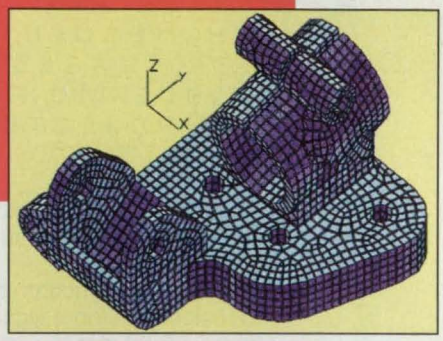




After Merlin™ one-step mesh enhancement technology



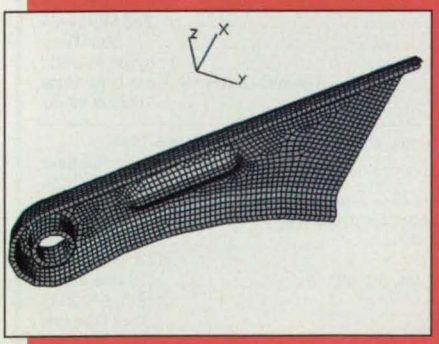


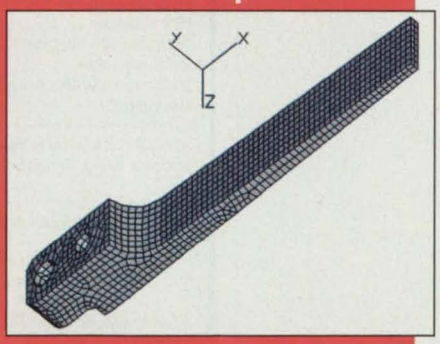


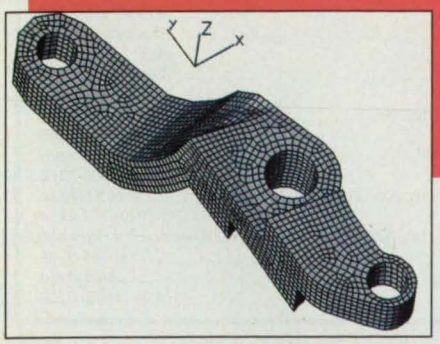
(Algor brick element models above shown with an 85% shrink-element factor.)

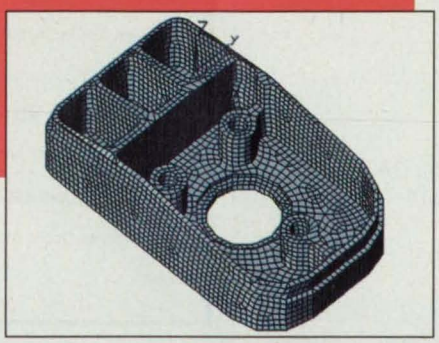
Merlin produces engineering-quality, quadrilateral surface meshes for high-accuracy plate/shell FEA or 8-node "brick" element generation using Hexagen (fully automatic). Merlin enhances the mesh quality of Algor's modeling and design software. In addition, Merlin is included in Houdini™ which is unique software that takes existing or new CAD solid models and automatically creates high-accuracy, 8-node "brick" finite element models.

Additional "After Merlin" Examples









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NASA Software of the Year Award

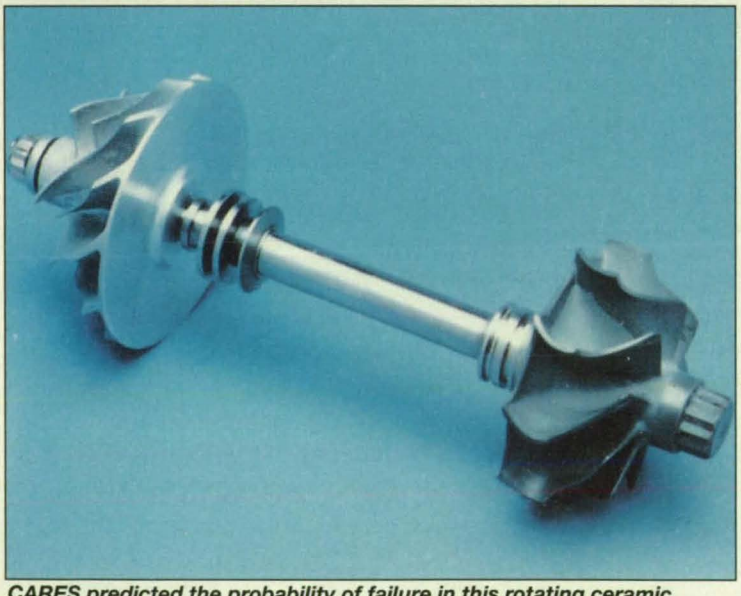
This year, two NASA divisions, the Office of Safety and Mission Assurance and the Inventions and Contributions Board, grant the first Software of the Year Award to two winners and three finalists. The award—a plaque and cash prize—goes to author(s) of software programs or technologies created by or for NASA and used in its space or aeronautics projects.

THE WINNERS

CARES/LIFE: Evaluating Ceramic Durability

In the search for stronger, lighter construction materials, ceramics have arisen as major alternatives to metallics, appearing in automotive engine components, high-temperature valves, heat exchangers, infrared windows, and artificial hips, knee caps, and teeth, where they are expected to take a lot of stress. CARES/LIFE, a software program developed at the Lewis Research Center, helps ensure that they will not buckle under the load.

John Gyekenyesi, head of Lewis' Structural Integrity Group, and his team began developing the program in the 1980s to predict the fracture response of ceramics due to flaws distributed in the structure's volume. From piece to piece, components made of a brittle material such as a ceramic can vary greatly in fracture behavior. Variations in apparently identical components arise from invisible material imperfections, which vary in magnitude. The structure fails when the strength of its weakest flaw is exceeded.



CARES predicted the probability of failure in this rotating ceramic turbine rotor for the Mitsubishi Motors Corporation.

Photo courtesy of NASA Lewis Research Center

Structural ceramics have at least two kinds of unavoidable flaws. One type—called volume or intrinsic flaws—comes about from material processing and is usually in the structure's interior. The other—surface or extrinsic flaws—arises from grinding, finishing operations, environmental factors, or the material's particular porosity intersecting with the structure's surface. Stress and fatigue on the structure lead to subcritical crack growth (SCG), which enlarges the cracks until they may cause catastrophic crack propagation. CARES/LIFE assesses the probability that the structure will fracture prematurely due to SCG as a function of service time.

For program operation, the designer must supply crucial information such as the shape, size, and composition of the component. Finite-element heat transfer and linear-elastic analyses determine its temperature and stress distributions. The program generates a data file of local reliability measures for a graphical representation of the structure's critical regions.

The CARES program offers a cost-effective way to test a ceramic component. "Normally we like to do a lot of paper studies, because computer simulation is relatively inexpensive," said Gyekenyesi. "You want to know as much as possible before doing prototype testing, which is usually very expensive."

The designer can rework the structure's components and test each configuration in computer simulation for its probabilities of failure. A key strategy is averaging the probable failures for individual copies, because CARES calculates the range of variations in each isomorph, according to the design and material. The designer can continue to adjust the design to maximize the projected durability.

Lewis engineers are designing and testing ceramics for "small" turbines—those that go into car, truck, helicopter, expendable missile, and small airplane engines ("large" turbines fit into 747s or larger machines). In fact, it was the push for lightweight, efficient, small-engine turbines that involved the center in ceramics research in the 1970s.

"The ceramics business came about," said Gyekenyesi, "because of the oil crisis in the 1970s and the establishment of the EPA. It was known that if monolithic ceramics could be used in engines, especially diesels, the combustion process could be made more efficient and reduce nitrous oxide, carbon

monoxide and other harmful pollutants." Ceramic parts could be used where the temperatures in a engine become very high, such as turbines, or in parts that move fast, such as valves; they would last longer, offer less resistance, and weigh less.

At the same time, the Department of Energy approached NASA seeking help in engine-efficiency research, which could fulfill the needs of both agencies and expand their horizons. "Recently, NASA has enlarged its mission, so we're also looking beyond aerospace applications," Gyekenyesi said.

INS3D, which simulates 3D viscous fluid flows, helped NASA redesign components of the space shuttle main engine including the above fuel pump impeller. *Photo courtesy Ames Research Center*

As the ceramics research progressed, NASA needed a general purpose simulation tool to predict the materials' durability. No code existed, so Gyekenyesi was assigned to devise one, and as the role his code played in ceramic component design increased, his team grew. In the meantime, the affordability of ceramic components increased enormously: originally costing about ten times the price of metallics, ceramics now come within 20 percent of the metallics' price in some applications.

Gyekenyesi described NASA's ceramics project as benefitting both the agency and the civilian sector. From the start of the project, two engine manufacturers, Garrett (Allied Signal) and Allison, have been major research benefactors. In turn, industry has benefitted from access to CARES: about 300 organizations worldwide have received it, with about 65 companies in the US using CARES/LIFE (an upgrade featuring ceramic life-prediction capability), which has only been released in this country.

Although similar codes now exist, Gyekenyesi attributed the popularity of CARES to two factors. The code is public domain and thus readily available. Further, it is integrated with popular finite element analysis programs such as ANSYS, NASTRAN, and ABACUS.

INS3D: Simulating Real-World Flows in 3D

In 1982, NASA sought to increase the thrust level in the space shuttle main engine (SSME) by nine percent. However, the gas flow in the engine was already so severe—so hot and under so much pressure—that the current engine couldn't accommodate the increase in thrust.

"Rocketdyne, the engine manufacturer, needed to redesign the engine power-head components," explained Dochan Kwak, acting chief of the Advanced Computational Methods Branch at Ames Research Center. "That's where computational fluid dynamics (CFD) came in, because building models takes a long time. CFD could help reduce the time and the cost involved in the redesign."

To meet the need for a simulation tool to analyze viscous incompressible flows such as those in the SSME, Ames scientists developed INS3D, an efficient and versatile computer code that solves incompressible Navier-Stokes equations in three dimensions, including moving boundary and unsteady flow capabilities.

"We made our impact at the early stages of the redesign," said Kwak, group leader of the INS3D project since its inception. "Think about cutting 20 different pieces of metal, assembling the engines, testing all of them, and then whittling out the bad choices. But we could do it practically—generating one solution each week. You just change the geometry, run the program, and compare the result with the previous ones."

Rocketdyne ran about 20 design variations using this code and chose the best configuration. Once constructed, the new engine proceeded to laboratory and full-scale testing. "They have produced flight engines that are undergoing extensive certification tests and are scheduled to fly next year," Kwak said.

Viscous incompressible flows or, alternatively, low-speed and friction-dominated flows, are not unique to the shuttle engine, nor is the application of INS3D limited to rockets.

"These kinds of flows happen all over. At the time it was being used in the SSME redesign, I studied the program and found several other potential applications such as commercial aircraft during landing and takeoff and a whole bunch of hydrodynamic problems," Kwak said.

The code has been used extensively in other NASA programs including the Advanced Subsonics Technology Program to analyze high-lift systems, the Propulsion CFD Consortium for the development of an advanced liquid rocket engine, and the vortex fence of a double-delta wing in the High-Speed Civil Transport program.

The INS3D code has been distributed by COSMIC to a wide variety of users in other government laboratories, universities, and industry. Meanwhile, Kwak's team has collaborated with the Navy on submarine flow analysis as well as worked with aircraft and automobile manufacturers to design aerodynamic shapes and solve internal flow problems. The code's greatest strengths are its accuracy, efficiency, and versatility. "Aerospace companies are very keen on these aspects, and they have chosen this code for their low-speed applications," he said.

One unexpected application of the code arose from the realization that the blood flow through an artificial heart also is viscous and incompressible. Explained Kwak: "We started with the Penn State artificial heart and then, a couple of years ago, began working on the NASA-Baylor College left ventricle assist device (LVAD), which is a rotating axial pump. We applied the code, which had been used for a fast-rotating rocket liquid pump, and had very good results."

Artificial heart assist devices experience major difficulties originating from fluid dynamics forces, including: clotting caused by separated and secondary flow regions; high turbulent shear stress damaging the red blood cells; and large pressure losses across the valves that prevent the heart from pumping efficiently. Having a detailed knowledge of the flow can help a design engineer improve the artificial heart assist device geometries.

Over the years, INS3D has gone through a series of upgrades that have improved its speed and accuracy. While the SSME work was done exclusively on Cray supercomputers, on which the code first was developed, INS3D is available now in workstation versions for smaller-scale analyses such as the LVAD.

NASA's future plans for INS3D include integrating it with wind tunnel experiments and extending it for parallel computing, which will enable integration with other disciplines such as optimization and structural analysis.

TAE Plus: A User Interface Development Tool

The available types of graphical user interfaces (GUI) are varied and expanding. Each time a user needs to create a new application with GUIs, however, it can be an arduous task, even for a programmer. To address this difficulty, NASA devised Transportable Applications Environment (TAE) Plus.

The need for such a program became apparent in the mid-1980s when affordable graphics workstations and windows programs became more common. "We wanted to separate the details of the user interface from the application, so that modifications to the GUI could be made independently and without having to rewrite any application-specific code," said Marti Szczur, TAE project manager at Goddard Space Flight Center, which developed the program with Century Computing, Inc.

TAE Plus was built on the concept of its earlier version, TAE Classic, which abstracted a core of system service routines and user dialogue sequences that could be used across a variety of applications. Written for ASCII alphanumeric terminals, TAE Classic was born when NASA's large-scale space operations demonstrated the need for rapid and efficient development of numerous computer programs. The process was streamlined by providing the developer with a consistent and standard menu presentation, error and information messages, parameter prompting, and clear command language. In other words, TAE Classic buffered changes in computer technologies and supported application portability across different computer systems.

TAE Plus applies to GUIs this idea of abstracting system service routines. It runs in two environments: design and run-time. In the design environment, the WorkBench (the WYSIWYG or "what you see is what you get") tool allows the developer to design the application's display layout and manipulate the interaction objects. These include user-entry objects (check boxes, pulldown menus, radio buttons) and data-driven objects (thermometers, dials, stripcharts, or a set of discrete pictures), which change in accord with real-time data. The developer specifies the interaction objects and windows that will comprise the user interface and the sequence of user interface dialogue.

In the run-time environment, the Window Programming Tools (WPTs) handle the management of the WorkBench-designed GUI. WPTs provide a set of routines that form a buffer between the underlying windowing system and the application code; they manage and display the user interface defined in the WorkBench. Thus, when changes are made to the window software, only changes to the WPTs are required—not to the application code.

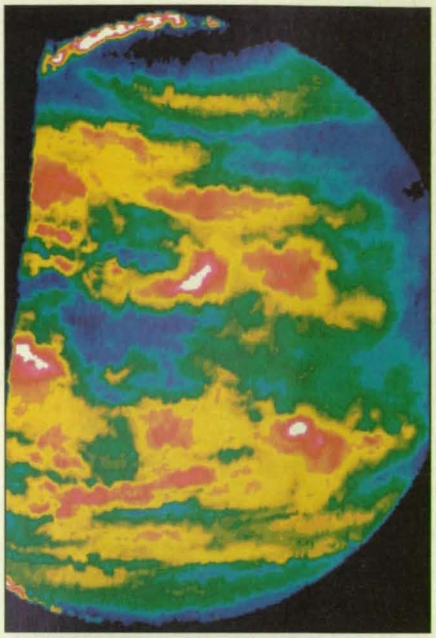
Over 1000 sites in goverrnment and academia have received TAE Classic or Plus. A user community has developed, with its own newsletter, conferences, and support office at Goddard.

VICAR/IBIS: Simplifies Image Processing

NASA has had a need to process images almost from the agency's inception. Early planetary exploration programs such as Ranger and Mariner required a way to remove photographic artifacts and the effects of transmitting images over noisy communications channels. Beginning in 1962, engineers at the Jet Propulsion Laboratory (JPL) turned to digital processing of the images as a first step in restoration and enhancement. This work led to the development of the Video Information Communication and Retrieval (VICAR) system, software that unifies and organizes image processing software. VICAR simplifies the acquisition, processing, and management of digital image data, thereby promoting image processing among diverse users.

The development of the Image-Based Information System (IBIS), a subset software system within VICAR, began with the need to integrate land use and land cover maps made by the Landsat satellite with a census tract file to derive land-use acreage per tract. This was only one instance of the general need to integrate land resource inventory data, generated by remote sensing imagery, with other kinds of geocoded statistics (such as graphic or tabular). Even the simplest case had required extensive image processing and data manipulation capabilities. Among the technical problems that IBIS solved was registering or indexing image data to spatially referenced tabular data so that a system could carry out processing that involved both types.

Available from COSMIC since 1973, with numerous upgrades and revisions, VICAR has gone out to over 100 institutions and companies across the globe for a wide array of applications. Besides planetary imaging, VICAR also supports image processing for astronomy, Earth resources, land use, biomedicine, and forensics. The program has influenced the design of many image-processing user interfaces, for such systems as the US Geological Survey's Planetary Image Cartography System, Khoros from the University of New Mexico, and Photoshop by Adobe Systems.



VICAR's many contributions to planetary imaging include this infrared map of the turbulent, cloudy middle atmosphere roughly 30 miles above the surface of Venus. The colors designate variations in cloud thickness.

Photo courtesy of Jet Propulsion Laboratory

Applications of IBIS have extended beyond planetary mapping to Earth modelling, including determining the location and amount of minable coal in an Illinois seam; analysis and modelling of potential debris slides in a national forest; displaying the health impact of an air pollution plume across Portland, Oregon; and biomass mapping in the California desert. IBIS set the trend for Geographic Information Systems, which had been based on vector graphics; as a raster-based image system, IBIS allowed greater functionality.

Building on the VICAR system, NASA established JPL's Image Processing Laboratory, now known as the Multimission Image Processing System (MIPS). The facility has served as a center of planetary imaging experiments, such as the Mariner and Viking Missions, and has produced atlases of Mars and Mercury. With a new client-server network at MIPS, scientists will be able to access MIPS and its data from their home institutions.

continued on page 101

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For More Information Write In No. 505

NASA PATENTS

Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. The agency has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

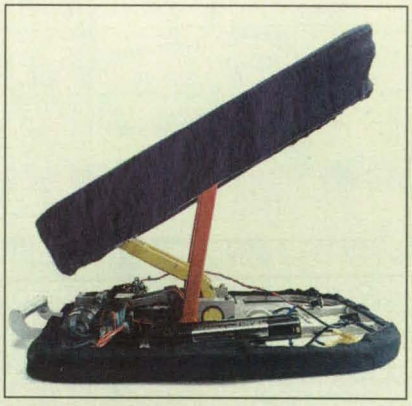
Wide Field Strip-Imaging Optical System

(US Patent No. 5,349,180)

Inventor: **Arthur H. Vaughan**, Jet Propulsion Laboratory

Applications such as terrain mapping, oceanographic studies, planetary exploration, and cloud surveillance require strip images having a 180-degree field of view. Unlike the commonly used fish eye lens, Mr. Vaughan's optical system can simultaneously image a 180-degree field of view with limited optical distortion, chromatic aberration, or thermal distortion. Inexpensive to construct and easy to maintain, it features a fiberoptic means for coupling to a detector array, spectrometer, or other instrument.

For More Information Write In No. 742



Portable Seat Lift

(US Patent No. 5,333,931)

Inventor: **Bruce Weddendorf**, Marshall Space Flight Center

Mr. Weddendorf has designed a portable seat lift to help physically impaired people either lower themselves into a sitting position or raise to a standing one. The device comprises a seat mounted with two levers to a base. The levers are powered by a drive unit that can completely lift the weight of a user. Both the front and back of the seat are raised in a manner that corresponds to how the backs of the thighs would normally approach or leave a chair.

For More Information Write In No. 740

Structures From Low Dielectric Polyimides

(US Patent No. 5,338,826)

Inventors: **Anne K. St. Clair**, **Terry L. St. Clair**, and **William P. Winfree**, Langley Research Center

Langley researchers have developed a means to produce structures that are effective as electrical insulators or as transmitter-receivers of electromagnetic energy. They are made by covering a suitable substrate with an adhering layer of a low dielectric, high temperature, linear aromatic polyimide.

For More Information Write In No. 741

Robot Friendly Probe and Socket Assembly

(US Patent No. 5,326,186)

Inventor: **Karen L. Nyberg**, Johnson Space Center

When performing work in an unfriendly environment, such as in space or undersea, it is best to minimize or eliminate human involvement. To that end, simplicity in design for structural joints and mechanical interfaces can enable robotic devices to be used for erection, repair, or maintenance of structures and equipment. A novel probe and socket assembly developed at Johnson for use as a mechanical interface between structures is adapted easily to robotic intervention. The assembly comprises a socket having a housing adapted for connection to a first supporting structure and a probe, which is in turn readily connectable to a second structure and designed to be grappled and manipulated easily by a robotic device.

For More Information Write In No. 743

Smart Accelerometer

(US Patent No. 5,309,149)

Inventor: **Richard J. Bozeman, Jr.**, Johnson Space Center

For years, vibration analysis has been used for early detection of malfunctions in machinery. It has been difficult, however, to prevent false signals from accelerometer transducers and related circuitry operating in a vibrating, electrically harsh environment. An improved accelerometer package contains both a transducer and the necessary frequency decoder circuitry used to provide a fault signal. This integrated "smart" package reliably monitors machines vibrations, regardless of unknown ground loops and electrical noise, and may be incorporated with an accelerometer case during the original manufacturing process or retrofitted into commercially available accelerometers.

For More Information Write In No. 744

High Temperature Creep and Oxidation Resistant Chromium Silicide Matrix Alloy Containing Molybdenum

(US Patent No. 5,330,590)

Inventor: **Sai V. Raj**, Lewis Research Center

Mr. Raj has employed molybdenum in a new chromium silicide alloy to improve high-temperature creep strength and oxidation resistance. The resulting two-phase microstructure of $(Cr,Mo)_3Si$ and $(Cr,Mo)_5Si_3$ forms two protective oxides over a wide range of temperatures. Chromium and molybdenum oxide volatize at temperature above 1200 °C, facilitating formation of SiO_2 on the surface. Below 1200 °C, Cr_2O_3 is formed.

For More Information Write In No. 745

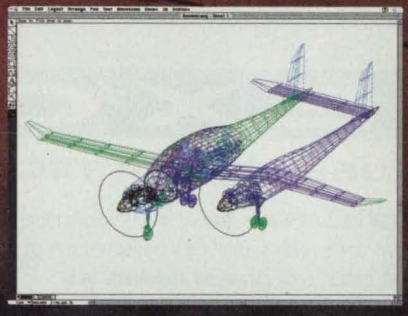
Burt Rutan Makes Vellum Fly

Two years after the Voyager completed its record-shattering around-the-world flight, you could still find its designer, Burt Rutan, working at a drafting table with pencil and paper.

Hardware wasn't the problem. He had computers. His company could buy any design system worth owning. What kept Burt grounded was software. CAD so clumsy, it squashed creativity. Or so weak, it simply couldn't do his job.

Maybe that's why the first time he sat down to design with Vellum®, Burt compared the experience to the exhilaration of flying. Vellum is the first CAD program with an autopilot.

Burt's creativity and willingness to explore uncharted territory is exemplified by this sneak peek at one of his latest designs produced (of course) in Vellum.



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Rather than force you to fight with the keyboard, or guess about alignment as you draw, Vellum pinpoints and spells out every logical design point for you, on screen. Draw a simple line and the midpoints, endpoints, and construction lines appear automatically. Click the mouse and you get precise alignment to 16 decimal places, instantly.

The Power of Parametrics

Before Vellum, using CAD for conceptual design was like trying to draw in the dirt with a backhoe. Vellum makes precise design as natural as free-hand sketching, with the combined power of Parametrics and Associative Dimensioning.

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According to Burt, "the only way to fully appreciate Vellum is to sit down and use it; tackle a tough job right off. See if the Drafting Assistant doesn't make you two, or even three times more productive than any other CAD package."

If you're like Burt Rutan, you'll find yourself using Vellum from conceptual design right through finished drawings. Best of all, you'll never give the drafting board, or another CAD program, a second thought.

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New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 20). NASA's patent-licensing program to encourage commercial development is described on page 20.

Porous Si_xGe_{1-x} Layers Within Single Crystals of Si

Electroluminescence from these layers might be utilized in novel optoelectronic devices. The development can lead to fabrication of new electroluminescent diodes, superlattices, and monolithic integration of lasers with Si circuits.
(See page 36.)

High-Performance Thermoelectric Semiconductors

Three compounds form solid solutions with exceptional thermoelectric and transport properties, opening up new possibilities in the development of more efficient thermoelectric power generators, coolers, and detectors.
(See page 52.)

Phenylethynyl-Terminated Polyimides

These polyimides can be synthesized at various molecular weights, which can be selected to obtain desirable properties in films, moldings, adhesives, and composite-material matrices.
(See page 52.)

Aromatic Polyimides With Low Dielectric Constants

In addition to their advantage as dielectric films in electronic circuits, these polyimides are nearly transparent and colorless, which makes them useful as protective coatings of solar photovoltaic cells, optical components, and antennas.
(See page 55.)

Stable, Electroinactive Wetting Agent for Fuel Cells

Straight-chain perfluorooctanesulfonic acid has been identified as an innocuous and stable wetting agent for use with polytetrafluorethylene-containing electrodes in liquid-feed direct-oxidation fuel cells like those suggested for vehicles and portable power supplies.
(See page 56.)

Geared Electromechanical Rotary Joint

This joint is designed to overcome some of the disadvantages of older electromechanical interfaces — especially the intermittency, and consequently electrical noise, of conventional sliding-contact and rolling-contact electromechanical joints.
(See page 71.)

Precision and Accuracy Driven by Intergraph

Computer-generated model of Nicklaus Golf's new "Bear" metalwood.

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We've outlined below NASA's Technology Transfer Network—named the participants, described their services, and listed the individuals you can contact for more information relating to your specific needs. We encourage you to make use of the information, access, and applications services offered.

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If you need further information about new technologies presented in NASA Tech Briefs, request the Technical Support Package (TSP). If a TSP is not available, you can contact the Technology Utilization Officer at the NASA Field Center that sponsored the research. He can arrange for assistance in applying the technology by putting you in touch with the people who developed it. If you want information about the patent status of a technology or are interested in licensing a NASA invention, contact the Patent Counsel at the NASA Field Center that sponsored the research. Refer to the NASA reference number at the end of the Tech Brief.

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If you represent a public sector organization with a particular need, you can contact NASA's Application Team for technology matching and problem solving assistance. Staffed by professional engineers from a variety of disciplines, the Application Team works with public sector organizations to identify and solve critical problems with existing NASA technology. **Technology Application Team, Research Triangle Institute, P.O. Box 12194, Research Triangle Park, NC 27709; Dr. Doris Rouse, Director, (919) 541-6980**

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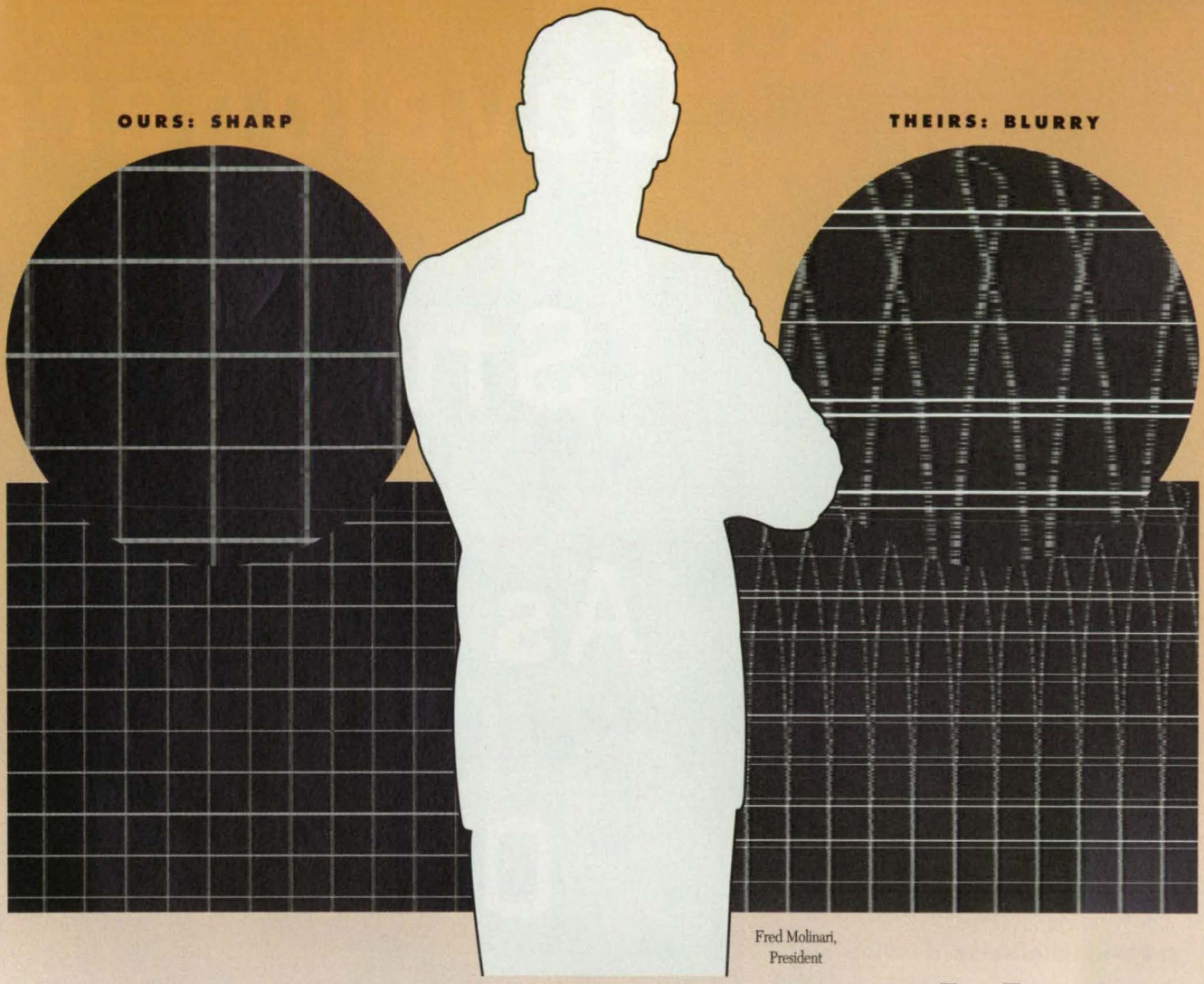
If You Have a Question..**NASA Center For AeroSpace Information** can answer questions about NASA's Technology Transfer Network and its services and documents. The CASI staff supplies documents and provides referrals. Call, write or use the feedback card in this issue to contact: NASA Center For AeroSpace Information, Technology Transfer Office, 800 Elkridge Landing Rd, Linthicum Heights, MD 21090-2934. Walter M. Heiland, Manager, (410) 859-5300, Ext. 245.



Fred Molinari,
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Special Focus: Test & Measurement

Automated System Tests High-Power MOSFET's

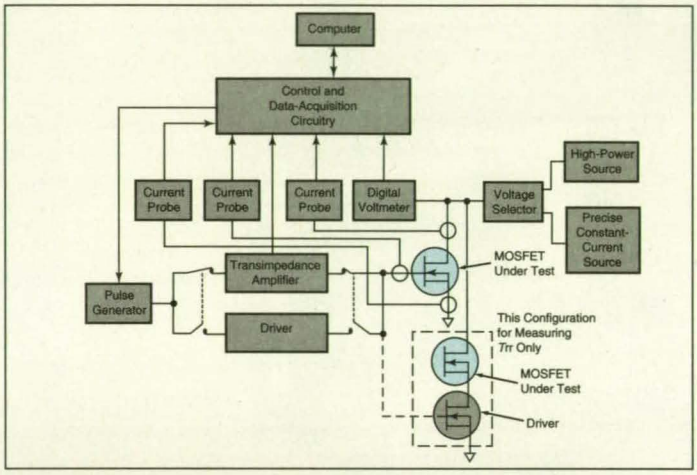
This system measures seven MOSFET parameters.

Lewis Research Center, Cleveland, Ohio

The figure shows the major functional blocks of a computer-controlled system that tests metal-oxide/semiconductor field-effect transistors (MOSFET's) at high voltages and currents. The system measures seven parameters that characterize the performance of a MOSFET, with a view toward obtaining an early indication that the MOSFET is defective: this is important because a short circuit can develop in a defective power MOSFET, with consequent destruction of other devices and equipment connected to the circuit in which the power MOSFET is installed. Thus, the use of the test system prior to installation of a power MOSFET in a high-power circuit can save time and money.

The seven parameters and the test performed by the system to determine these parameters are as follows:

1. Gate-source leakage current (Igss). This parameter is a measure of the effectiveness of the oxide layer in the gate of the MOSFET. Positive and negative voltages are forced on the gate while the drain and source are held at ground potential and the leakage current is measured. A high leakage current implies that the gate is damaged.
2. Gate threshold voltage (Vgsth). This parameter indicates the lowest gate voltage needed to turn on the MOSFET. It is defined as the gate voltage at which a specified small current (2 mA) begins to flow in the MOSFET drain with VGS =VDS.



This **Automated System** measures seven parameters of the MOSFET under test to obtain an early indication that the MOSFET is defective.

3. Drain/source breakdown voltage (BVdss). This is the maximum voltage that can be applied to the MOSFET from the drain to the source with VGS = 0. This parameter is determined by forcing a current of 6 mA into the drain and measuring the voltage.
4. Drain current at zero gate voltage (Idss). This is the drain current with the MOSFET gate tied to ground and the drain-to-source voltage set at 450 V.
5. Total gate charge (Qgtot). This is the total charge that must be supplied to the MOSFET gate by the drive circuitry to change the gate voltage from 0 V to 10 V. The Qgtot defines the peak current required from the driver and the average current needed for switching the MOSFET. This parameter is measured by pulsing the MOSFET gate and applying 250 V from the drain to the source using the precise constant current source.
6. Gate charge, gate to drain (Qgd). This parameter represents that portion of Qgtot that charges the gate-to-drain capacitance. This can also be regarded as the amount of charge that must be transferred to the gate in order to get the drain-to-source voltage to go through its transition.
7. Diode reverse recovery time (Trr). This is the time it takes the inherent drain-to-source diode to return to a reverse-bias state.

This work was done by Steven W. Huston and Isabel O. Wendt of Rockwell International Corp. for **Lewis Research Center**. *No further documentation is available.*

LEW-15255

Bag Test Measures Leakage From Insulated Pipe

An impermeable bag and calibration leaks are used.

Marshall Space Flight Center, Alabama

A test quantifies the leakage of gas from a pipe even though the pipe is covered with insulation. The test involves the use of a helium analyzer to measure the concentration of helium in an impermeable bag around the pipe.

The test is administered after a standard soap-solution bubble test has indicated the presence and general class of leakage. (Soap solution is brushed on the insulated pipe. If bubbles form, a leak is present; the size of the bubbles indicates whether the leak is of class I, II, or III, in order of ascending magnitude.) The helium-impermeable bag is taped around the affected part of the pipe (see figure).

The bag is then calibrated as follows: It is purged with gaseous nitrogen, then helium is fed into it at one end via a flow meter at a known volumetric rate of

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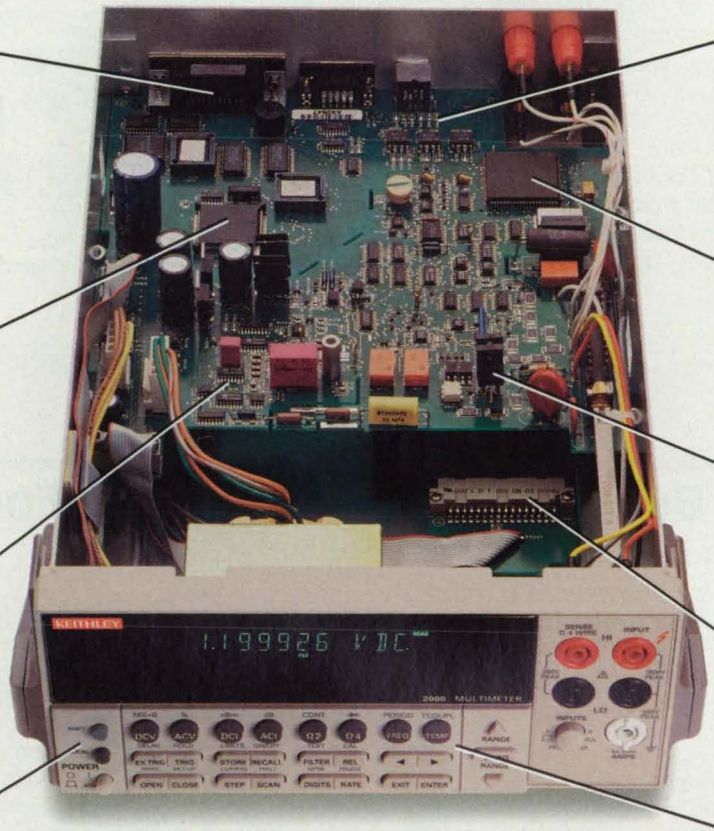

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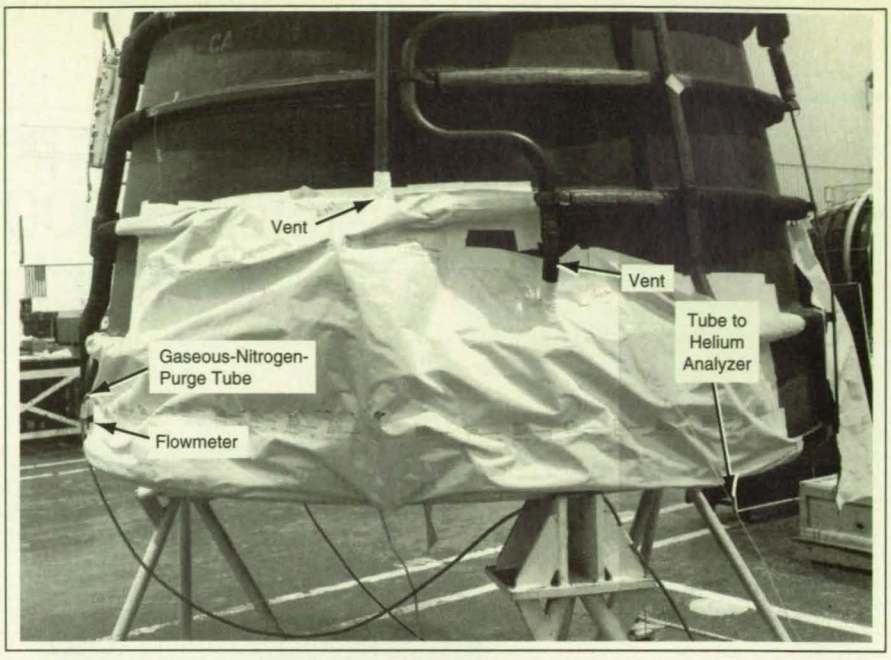
flow. At the opposite end of the bag, a helium analyzer measures the concentration of helium as a function of time. This procedure is repeated at various rates of flow, and the results for each rate of flow are plotted as concentration versus time. These plots serve as calibration curves for the measurement of leakage at the various rates of flow.

The leak test proper can then be performed. The bag is purged with nitrogen, and the pipe is pressurized with helium at a gauge pressure of 25 lb/in.2 (0.17 MPa). The concentration of helium created by leakage from the pipe is measured as a function of time. The rate of increase of concentration is compared with the previously established calibration curves to determine the rate of leakage.

This work was done by Kent D. Schock and Barry P. Easter of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 130*** *on the TSP Request Card.*
MFS-29902



The **Bag Is Taped** over the leaky part of a pipe. Here the test is performed on hydrogen-coolant tubes on the Space Shuttle main engine.

Instrumented Bolts Would Measure Shear Forces in Joints

Strain gauges would be mounted in small recesses on the bolts.

Langley Research Center, Hampton, Virginia

Bolts instrumented with strain gauges would be used to measure shear forces, according to a proposal. More specifically, the instrumented bolts would be installed in multiple-bolt lap joints to obtain data on the distribution of stresses and deformations in and around the joints. The strain gauges would indicate the share of the applied load borne by each individual bolt, thus contributing to an understanding of the combined effects of applied loads, friction, and yielding of the bolted materials.

In the original intended application, the bolted panels would be made of advanced refractory composite materials designed to withstand use at temperatures up to 4,000 °F (about 2,200 °C). Because these materials are generally brittle, joint-design techniques for metals and other materials that yield substantially under stress cannot be used. The development of reliable joint-design techniques will depend on data on stresses deep within bolted joints — data that heretofore could be acquired only with great difficulty, but could now be acquired more easily by use of the proposed instrumented bolts.

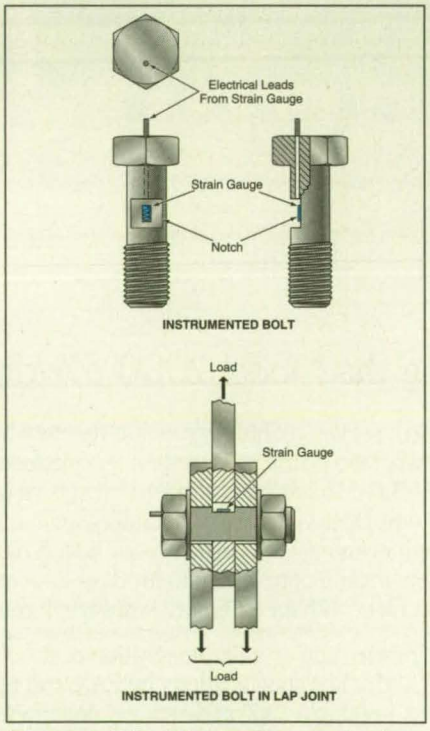


Figure 1. The **Single-Gauge Instrumented Bolt** would be sensitive to bending strain. In a lap joint, the notch and gauge would be made to face away from the point of application of the load.

The concept of instrumented bolts is also applicable to other joint materials and to measurement of shear loads in other connections — for example, shear loads on shafts in pulleys or gears.

To ensure a realistic distribution of stresses, an instrumented bolt would be made from a bolt of the same size and material as would be used in a practical version of the joint. The strain gauges could be installed in the bolt in any of a number of alternative configurations. Two useful configurations would be (1) a single strain gauge that would be sensitive to bending strain and (2) two pairs of strain gauges oriented so that in combination they would be sensitive to shear strain.

In the single-strain-gauge version, the gauge would be potted in a flat notch machined in the shank of the bolt (see Figure 1). Electrical leads would be routed from the gauge through an axial hole in the shaft and out through the head of the bolt. The diameter of the axial hole and the depth and width of the notch should be kept as small as possible to minimize the effect on shear and bending strength. The length of the notch should not exceed the thickness

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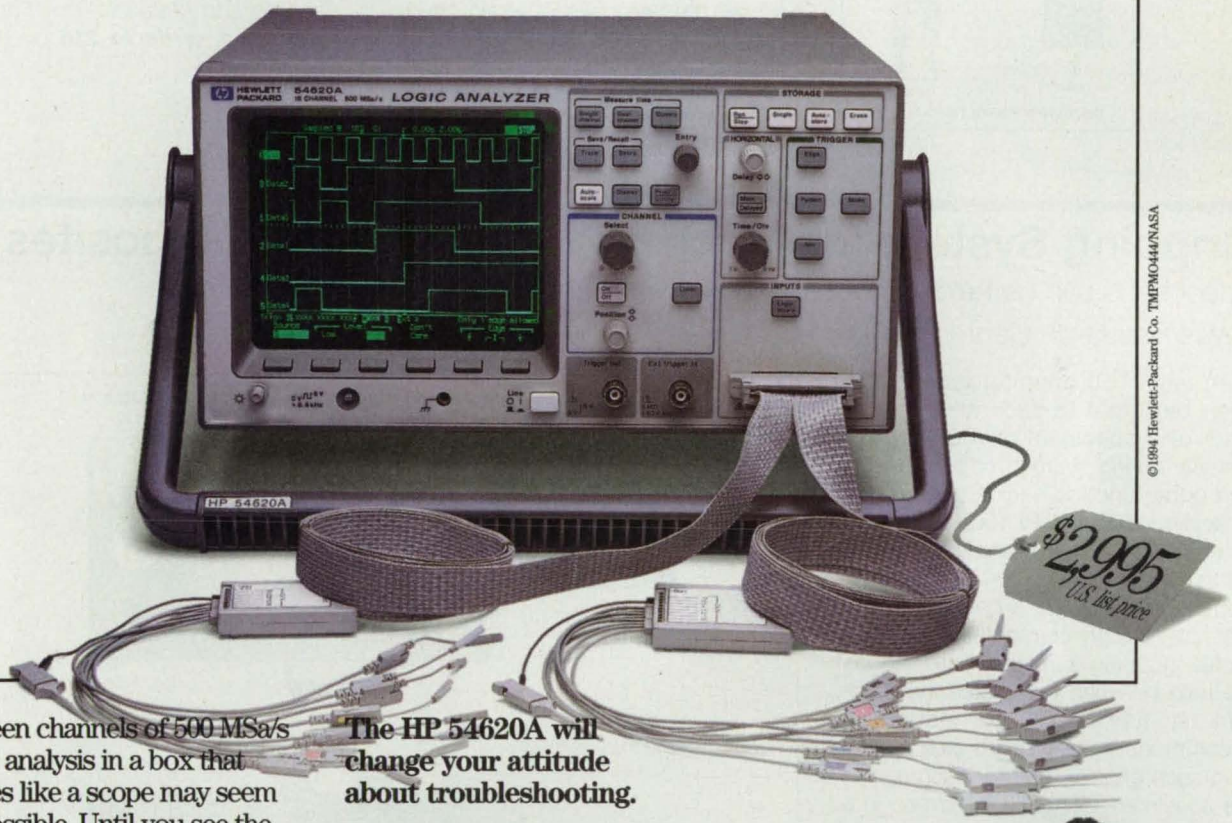

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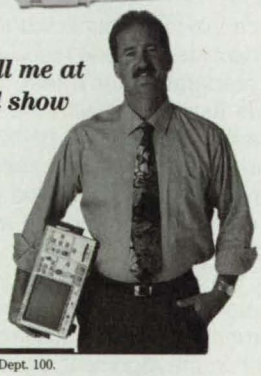

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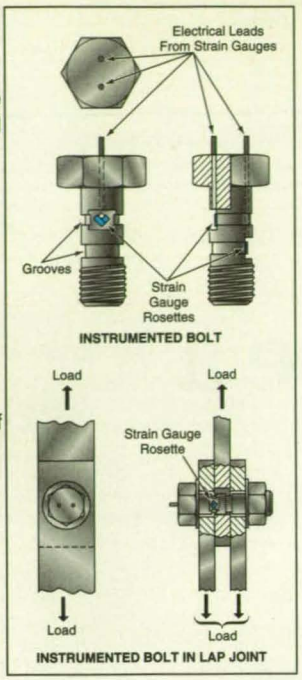


Figure 2. The **Four-Gauge Instrumented Bolt** would be sensitive to shear strain. In a lap joint, the centers of the strain-gauge rosettes would be located in the planes of the faying surfaces.

of the panel to be bolted.

The instrumented bolt could be placed, for example, in a double-lap joint with the bolt turned to position the notch on the side 180° away from the point of application of the load to the joint. The strain gauge would sense the bending strain produced by the load. The gauge would be calibrated by correlation of its readings with known applied loads. Calibration would have to be performed with materials of the same thickness and with the bolt and nut tightened to the same torque as in the practical joint represented by the test joint. The lap ped panels should be polished and lubricated to minimize calibration error from friction.

In the other version of the instrumented bolt, the two pairs of strain gauges would be installed in two flat notches on opposite sides of the bolt (see Figure 2). Circumferential grooves only a few thousandths of an inch deep (0.001 in. = 0.0254 mm) and slightly wider than a strain gauge would reduce the variation in the shear load over the width of each gauge. The instrumented bolt could be placed in a double-lap joint with the planes of the strain gauges parallel to the loading plane of the joint. The strain gauges in each notch would be arranged in a rosette at ±45° to the axis of the bolt. The centers of the rosettes must be in the planes of the faying surfaces of the joint. The gauges would sense the shear strain in the loaded joint, which again could be related to the applied load by calibration.

This work was done by James Wayne Sawyer of **Langley Research Center** *and Robert R. McWithey of Analytical Services and Materials, Inc. For further information,* ***write in 215*** *on the TSP Request Card.*
LAR-14622

Gripping System for Mechanical Testing of Composites

Specimens can be held without slippage, even at high temperatures.

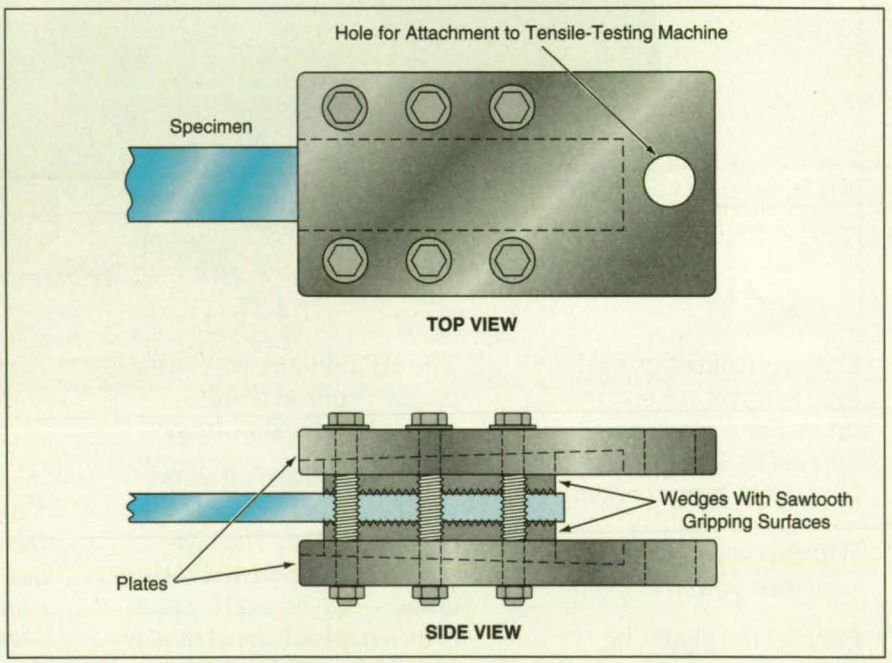
Lewis Research Center, Cleveland, Ohio

An improved gripping system has been designed to securely hold the ends of a specimen of a composite material during a creep or tensile test. The grips function over a wide range of applied stress [3 to 100 kpsi (about 21 to about 690 MPa)] and temperature [up to 1,800 °F (about 980 °C)].

Each grip includes a pair of wedges that have sharply corrugated (sawtooth-profile) gripping surfaces. The wedges are held between two plates that contain cavities which are sloped to accommodate the wedges (see figure). Two such grips — one for each end of the specimen — hold a specimen in a furnace which is connected to a tensile test machine for creep measurements.

In preparation for a test, the specimen is assembled with the grips in a fixture that maintains all parts in precise alignment: this step is necessary to ensure that the load applied during the test will coincide with the axis of the specimen. Unlike some older wedge grips, the specimen can be gripped in a delicate manner during assembly and alignment. While the assembled parts are still in the alignment fixture, hexagonal nuts and bolts on the grip can be tightened evenly with a torque wrench to 120 lb.-in. (≈ 13.6 N-m).

During a test, the grips apply the required tensile stress to the specimen without slippage at high temperatures and, therefore, without loss of alignment. In contrast, some older plate grips tended to slip at high temperatures when applied tensile stresses rose above 20 kpsi (≈ 140 Mpa), while older hydraulically actuated grips had to be kept outside the testing furnaces which introduced temperature gradients in the specimens.



A **Pair of Sawtooth Wedges** clamped between a pair of plates holds one end of a specimen. A mirror image of this grip is attached at the other end of the specimen. An alignment fixture (not shown) holds the grips and specimen during assembly.

This work was done by Rebecca A. MacKay and Michael V. Nathal of **Lewis Research Center.** *For further information,* ***write in 217*** *on the TSP Request Card.*
LEW-15345

Program Helps Design Tests of Developmental Software

Technically effective and economically feasible test cases are formulated

A computer program called "A Formal Test Representation Language and Tool for Functional Test Designs" (TRL) provides an automatic software tool and a formal language that is used to implement the category-partition method and produce the specification of test cases in the testing phase of the development of software. The category-partition method is particularly useful in defining the input, outputs, and purpose of the test-design phase of development and combines the benefits of choosing normal cases that have error-exposing properties. Traceability can be maintained quite easily by creating a test design for each objective in the test plan. The effort to transform the test cases into procedures is simplified by use of an automatic software tool to create the cases based on the test design. The method both enables the rapid elimination of undesired test cases from consideration and facilitates review of test designs by peer groups.

The first step in the category-partition method is functional decomposition, in which the specification and/or requirements are decomposed into functional units that can be tested independently. A secondary purpose of this step is to identify those parameters of each functional unit that affect the behavior of the system. In the second step, called "category analysis," the work done in the previous step is carried further by determining the properties of sub-properties of the parameters that would make the system behave in different ways. The designer should analyze the requirements to determine the features or categories of each parameter and how the system may behave if the category were to vary its value. If the parameter undergoing refinement is a datum, then categories of this datum can be any of its attributes; for example, type, size, value, units, frequency of change, or source.

After all the categories for the parameters of the functional unit have been determined, the next step is to partition the range space of each category into mutually exclusive values that the category can assume. In choosing partition values, all possible kinds of values should be included – especially the ones that will maximize the detection of errors. The final step is called "partition constraint analysis"; Its purpose is to refine the test design specification so that only the technically effective and economically feasible test cases are implied.

TRL is written in C language to be machine-independent. It has been successfully implemented on an IBM PC-compatible computer running MS-DOS, a Sun4-series computer running SunOS, an HP 9000/700-series work station running HP-UX, a DECstation computer running DEC RISC ULTRIX, and a DEC VAX-series computer running VMS. TRL requires 1Mb of disk memory and a minimum of 84K of random-access memory. The documentation is available in electronic form in WorkPerfect format. The standard medium for distribution of TRL is a 5.25-in. (13.335-cm), 360K, MS-DOS-format diskette. Alternate distribution media and formats are available upon request. TRL was developed in 1993 and is a copyrighted work with all copyright vested in NASA.

This program was written by Jonathan Hops of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 212*** *on the TSP Request Card. NPO-19279*

The Anderson Current Loop

The four-wire-probe concept is applied to electrical-resistance transducers.

Dryden Flight Research Center, Edwards, California

The Anderson current loop is an excitation-and-signal-conditioning circuit suitable for use with strain gauges, resistance thermometers, and other electrical-resistance transducers that are mounted in harsh environments. It can be used as an alternative to the Wheatstone bridge. It simplifies the signal-conditioning problem in that it enables precise measurement of small changes in the resistance of a transducer, even in the presence of large random variations in wire resistances, and with excitation by an unregulated power supply.

The Anderson current loop was devised to eliminate some of the uncertainties in Wheatstone-bridge resistance-change measurements in flight research. In a Wheatstone bridge, lead-wire and contact resistances, which can fluctuate, exert significant unknown effects on the measurements of gauge resistances. The great advantage of the Anderson current loop is that its configuration makes the effects of lead-wire and contact resistances insignificantly small, so that these unknown resistances become irrelevant, even for single-gauge sensors. Furthermore, unlike a Wheatstone bridge, the Anderson current loop provides an output voltage that varies linearly with the change in gauge resistance, and does so at double the sensitivity of a Wheatstone bridge.

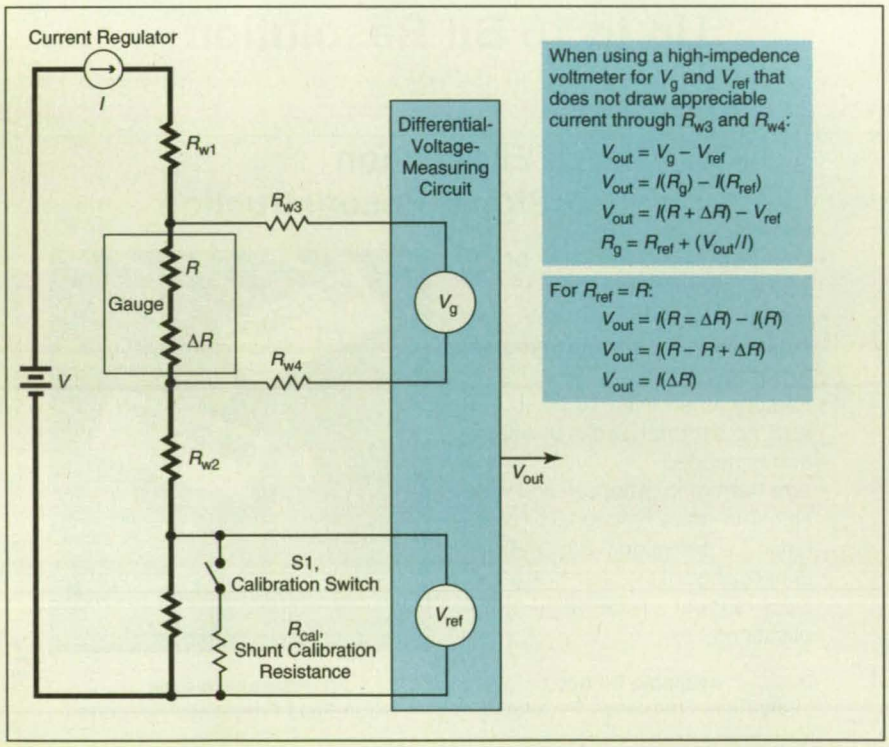


Figure 1. The **Fundamental Anderson Current Loop** puts out a voltage proportional to the difference, ΔR, between the gauge and reference resistances. The lead-wire resistances, R_{w1} through R_{w4}, do not appear in the equations for V_g, V_{ref}, and V_{out}. Thus, the circuit is insensitive to changes in these resistances.

The key to preventing contamination of readings by voltage drops in the lead wires is simply to exclude these voltage drops from the measurements. There is no way to exclude them in the classic Wheatstone bridge circuit. In the Anderson current loop, voltage drops in the lead wires are excluded by use of the well-known four-wire-probe technique, in which a known current is supplied via two lead wires to a resistance to be determined, and the voltage across this resistance is coupled to a high-input-resistance voltmeter via two other lead wires.

The resistances of the current-supplying lead wires are irrelevant because the voltage across the resistance to be determined depends only on the current (which is known) and on the resistance; the resistances of the voltage-coupling wires are irrelevant because, by virtue of the high input resistance of the voltmeter, the currents in these wires and thus the voltage drops in these wires are negligibly small.

In the fundamental Anderson current loop (see Figure 1), the source of current is connected to a gauge resistance, R_g (the resistance to be determined) in series with a reference resistance, R_{ref}. The voltages across these resistances (V_g and V_{ref}, respectively) are simultaneously measured. The two wires carrying V_g and the two wires carrying V_{ref} are connected to the four input terminals of a dual-differential voltage-measuring circuit. The inputs to this circuit can be processed by commercial integrated-circuit instrumentation amplifiers.

The current-loop concept enables the use of fewer and smaller lead wires with such multi-gauge sensors such as strain-gauge rosettes. In the rosette application, a single temperature-compensating gauge provides corrections for apparent strains for three or more strain gauges in a single-loop circuit. A set of three 350-Ω strain gauges connected to signal-conditioning circuitry with a total of six lead wires yields stable readouts, even when the resistances of individual lead wires are varied randomly from near 0 to over 100 Ω. Several hundred measurement channels based on the current-loop concept are used daily at Dryden Flight Research Center to condition signals from strain gauges in hot testing environments.

Figure 2 illustrates the addition of a circuit in which a circuit that computes a ratio between two voltages has been added to the fundamental Anderson

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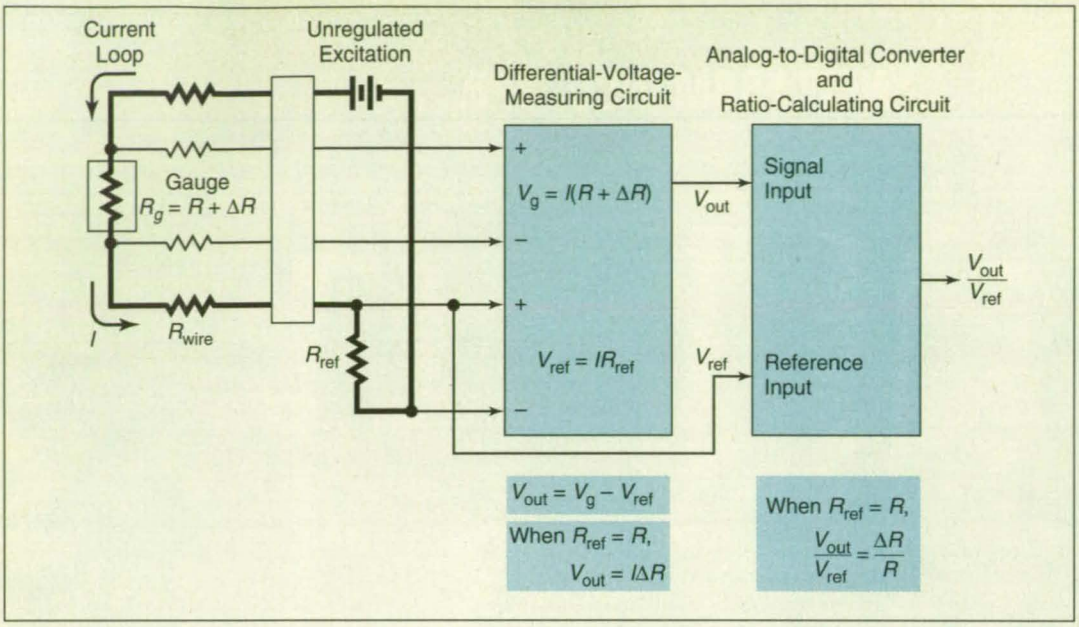


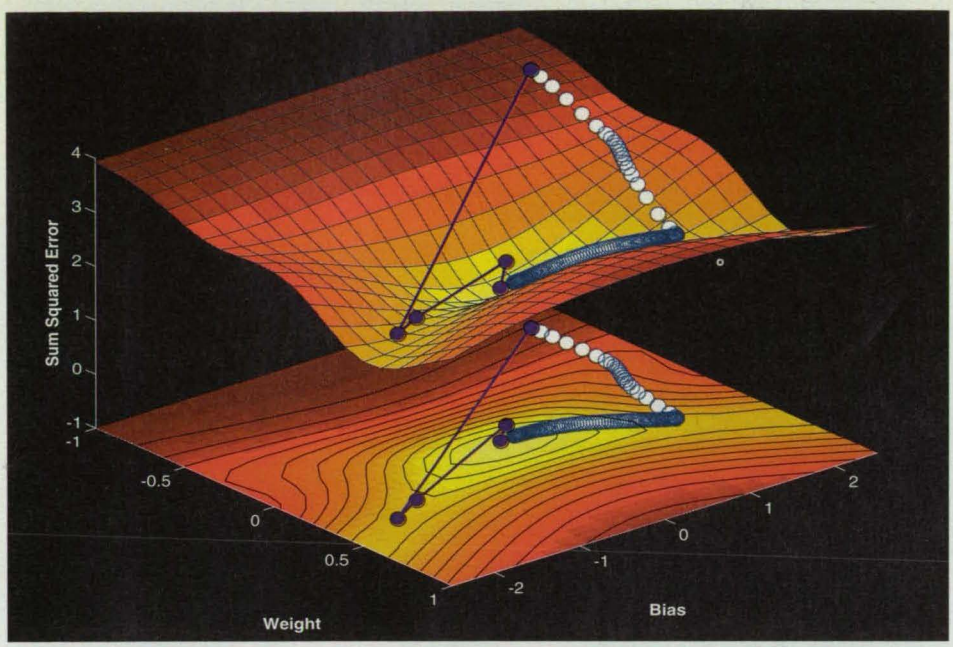
Figure 2. **Unregulated Excitation** need not inhibit the acquisition of data on ΔR. The computation of V_{out}/V_{ref} yields $\Delta R/R$, independent of the current I.

current loop. The output of this circuit is stable even when the Anderson current loop is excited by an unregulated voltage. Stable measurements can be obtained, for example, when the gauge is excited by a common 9-volt battery.

This work was done by Karl F. Anderson of **Dryden Flight Research Center**. *Further information may be found in NASA TM-104260 [N93-12681/TB], "The Constant Current Loop: A New Paradigm for Resistance Signal Conditioning," and NASA TM-104271 [N94-15754/TB], "Simultaneous Measurement of Temperature and Strain Using Four Connecting Wires."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, User Services Division, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Dryden Flight Research Center [see page 20]. Refer to DRC-00001.



MATLAB graphics enhance understanding of neural network behavior. This plot compares training rates for standard backpropagation (white, 108 steps) and the fast Levenberg-Marquardt algorithm (blue, 5 steps). Each trace illustrates the number of steps from initial conditions to the minimum error.

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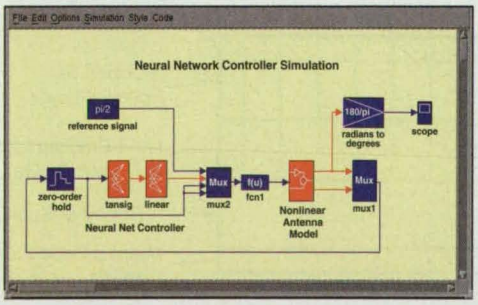

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Porous Si_xGe_{1-x} Layers Within Single Crystals of Si

Electroluminescence from these layers might be utilized in novel optoelectronic devices.

NASA's Jet Propulsion Laboratory, Pasadena, California

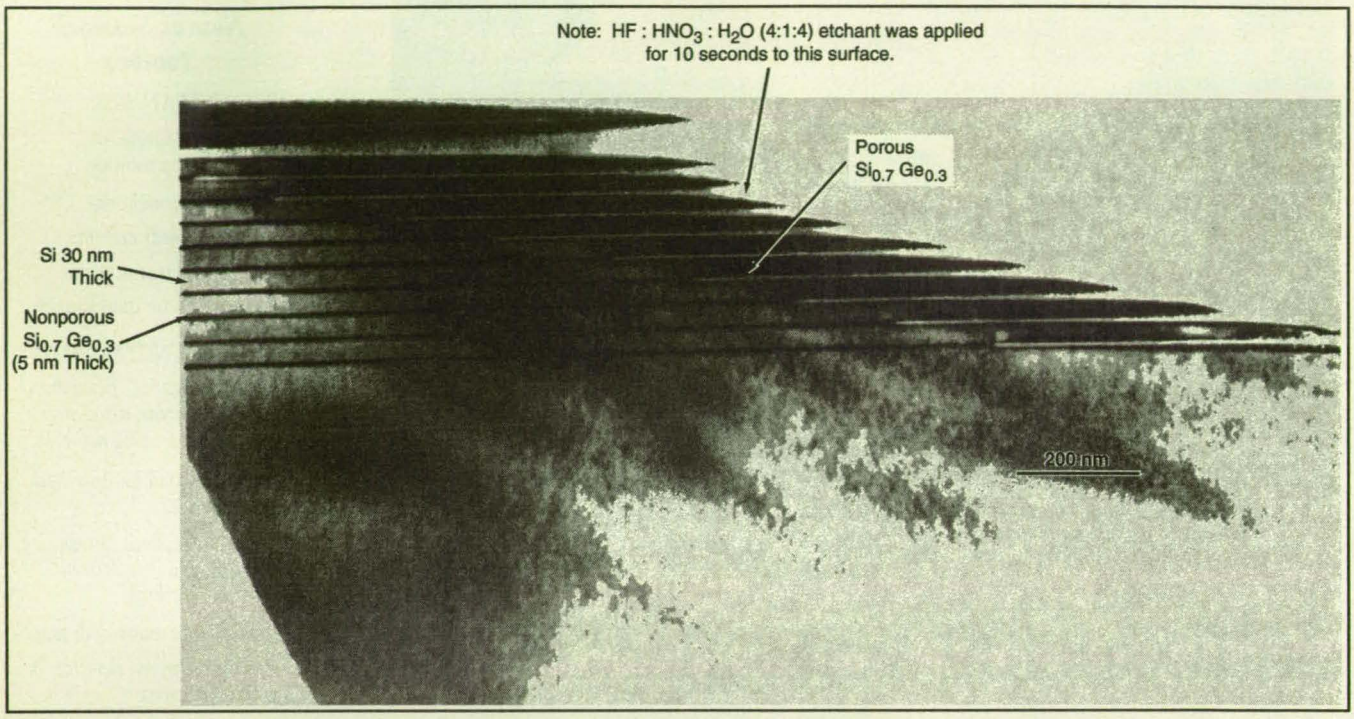


Figure 1. This **Cross-Sectional Transmission Electron Micrograph** shows that the porosity in the $Si_{0.7}Ge_{0.3}$ layers extends from the right side (where the etching solution made contact) leftward part way along these layers.

Layers of porous Si_xGe_{1-x} buried within single crystals of Si can be formed by epitaxial growth of $Si/Si_xGe_{1-x}/Si$ structures followed by etching in solutions of $HF:HNO_3:H_2O$. This fabrication process has been investigated with a view toward development of novel optoelectronic devices in which electroluminescence occurs in porous Si_xGe_{1-x} layers.

Electroluminescent devices that consist of layers of porous Si between metal electrodes have also been investigated and found to be deficient for reasons that relate to the direct contact between metal and porous Si. It would be preferable to make indirect electrical contact with porous Si layers via single-crystal layers of Si. Before the present fabrication process was conceived, there was no practical way to form the desired single-crystal/porous/single-crystal structures.

In experiments performed initially to demonstrate the fabrication process, undoped layers of Si_xGe_{1-x} 5 nm thick were grown epitaxially between layers of Si 30 nm thick. In some specimens, x was 0.94; in others, it was 0.7. The stacked layers were plasma-etched to form mesa structures and thereby make the edges of the layers accessible for chemical etching. These specimens were exposed to solutions of $HF:HNO_3:H_2O$ in volume proportions of 4:1:4 and, in some cases, 4:1:6. These solutions stain etched Si_xGe_{1-x} preferentially over Si, forming pores in the Si_xGe_{1-x} layers at a rate at least 100 times that in the Si layers (see Figure 1). Transmission electron diffraction analysis of the porous regions showed that they were probably amorphous (with respect to crystalline structure).

One potential application lies in fabrication of an electroluminescent diode. An epitaxial layer of Si_xGe_{1-x} could be grown on an n-doped Si substrate, then capped with an epitaxial layer of p-doped Si. The Si_xGe_{1-x} layer could then be converted to light-emitting porous material by preferential stain etching in $HF:HNO_3:H_2O$. A back-side metal electrical contact and a front-side semitransparent electrical contact (possibly of lead/tin oxide or heavily doped silicon) could then be added to complete the diode structure (see Figure 2).

Another potential application lies in Si/porous Si_xGe_{1-x}/Si superlattices, which are expected to have novel optical and/or optoelectronic properties. Such a structure may be similar to that shown in Figure 1, except that all of each SiGe layer would be converted to porous material.

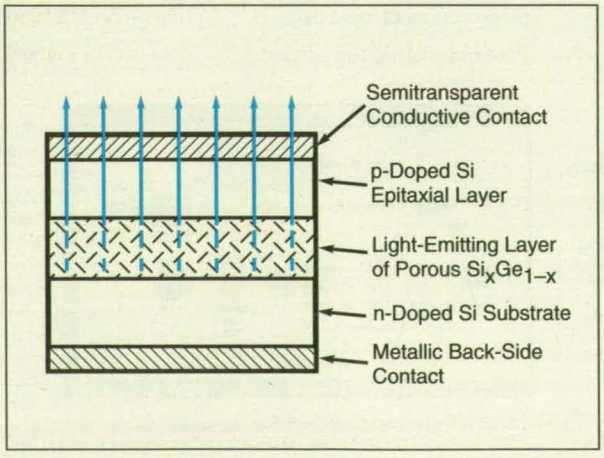


Figure 2. This **Electroluminescent Diode Structure** could be fabricated by the selective-etching technique described in the text. Voltage applied to the contact would make current flow vertically through the porous Si_xGe_{1-x} layer, resulting in emission of photons.

In a variation of the concept, a solution (perhaps hydrofluoric acid) that attacks Si_xGe_{1-x} much more than it attacks Si might be used to etch away an underlying porous SiGe layer, leaving a top Si layer intact. If the Si top layer had been processed to form an integrated circuit or other device, and if the device structure were suitably protected, the entire circuit could be lifted off and placed on a compound semiconductor chip. This would enable monolithic integration of such compound semiconductor devices as lasers with the Si circuit (which might have, for example, a high level of digital functionality).

This work was done by Robert W. Fathauer and Thomas George of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 34*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL [See page 20]. Refer to NPO 18836.

Making Porous Luminescent Regions in Silicon Wafers

Regions damaged by ion implantation are stain-etched.

NASA's Jet Propulsion Laboratory, Pasadena, California

Porous regions within single-crystal silicon wafers can be fabricated by a straightforward stain-etching process. These regions exhibit visible photoluminescence at room temperature and thus might constitute the basis of a novel class of optoelectronic devices.

A related development was reported in the preceding article, "Porous Si_xGe_{1-x} Layers Within Single Crystals of Si." As explained in that article, $Si/Si_xGe_{1-x}/Si$ structures were exposed to solutions of $HF:HNO_3:H_2O$, which etched and formed pores in Si_xGe_{1-x} layers about 100 times as fast as in the adjacent Si layers.

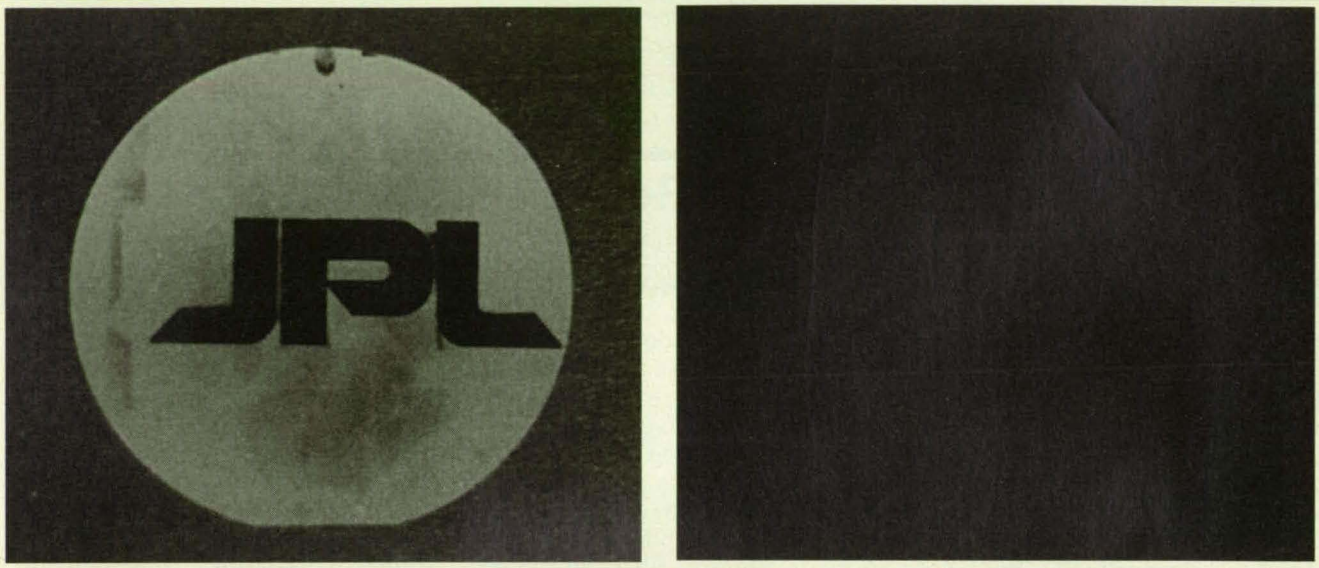
In the present stain-etching process, the first step is to coat the wafer with photoresist, which is then patterned photolithographically to expose the surface of the silicon in the region to be made porous. Next, silicon or boron ions are implanted in the exposed area. When the wafer is subsequently exposed to a solution of $HF:HNO_3:H_2O$, the region damaged by the implantation of ions becomes etched and porous much more rapidly than does the surrounding undamaged silicon.

This stain-etching process appears to have some advantages over a recently investigated anodic-etching process. The stain-etching process works on both n-doped and p-doped silicon wafers. The figure shows a specimen that was implanted with boron ions at a kinetic energy of 15 keV and a dose of 1015 cm^{-2} in the pattern of the "JPL"

logotype, then etched. When illuminated by ultraviolet light the pattern exhibited red-orange luminescence that was visible to the naked eye.

This work was done by Robert W. Fathauer and Eric W. Jones of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 112*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL [see page 20]. Refer to NPO-18735.



RED/ORANGE LUMINESCENCE UNDER ULTRAVIOLET LIGHT **APPEARANCE UNDER WHITE LIGHT**

Boron Ions Were Implanted in this silicon wafer in the region of the "JPL" logotype, then the wafer was etched to make the ion-damaged region porous. The region luminesces visibly.

Epitaxial Deposition of Germanium Doped With Gallium

High-quality material would be useful in infrared sensors.

NASA's Jet Propulsion Laboratory, Pasadena, California

Epitaxial layers of germanium doped with gallium would be made by chemical vapor deposition, according to a proposal. Highly pure epitaxial germanium doped with gallium is needed for state-of-the-art infrared sensors.

Films of germanium have been made previously by various chemical vapor deposition processes, including thermal decomposition of GeH_4, plasma decomposition of GeH_4, and reduction (by H_2) of halides of Ge ($GeCl_4$ and $GeBr_4$). Films of gallium have been made previously by chemical vapor deposition from $GaCl_3$. The proposed method would involve a combination of

techniques and materials used previously; namely, chemical vapor deposition with GeH_4 or $GeCl_4$ as the source of germanium and $GaCl_3$ as the source of gallium. The resulting epitaxial layers of germanium doped with gallium are expected to be highly pure, with high crystalline quality.

This work was done by James E. Huffman of Rockwell International Corp. Science Center for **NASA's Jet Propulsion Laboratory**. *No further documentation is available.*
NPO-18961

Radiation-Protected Protocols for Self-Testing of Microcircuits

Ionizing radiation need not trigger unintended self-testing.

NASA's Jet Propulsion Laboratory, Pasadena, California

Protocols installed in certain microcircuits that permit functional self-testing do not consider the possibility of inadvertent triggering by protons or energetic heavy ions in space or satellite orbit. It is recommended that these devices be rendered immune to so-called single event effects of energetic ions in cosmic rays, flares, or trapped-charge belts surrounding Earth and some other planets. It is proposed that a pair of stimuli be applied to the device in a specified manner in order to start the self-test. The protocol can require two or more stimuli at a single node, or a pair of stimuli at two nodes, or some more complicated combination.

The important realization is that existing self-test mechanisms will be triggered unless removed or rendered immune as described above. An unintended transition to the self-test mode could have disastrous consequences in many applications in space or satellite orbit.

This work was done by Donald K. Nichols of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 154*** *on the TSP Request Card.*
NPO-19047

Digital-Electronic/Optical Apparatus Would Recognize Targets

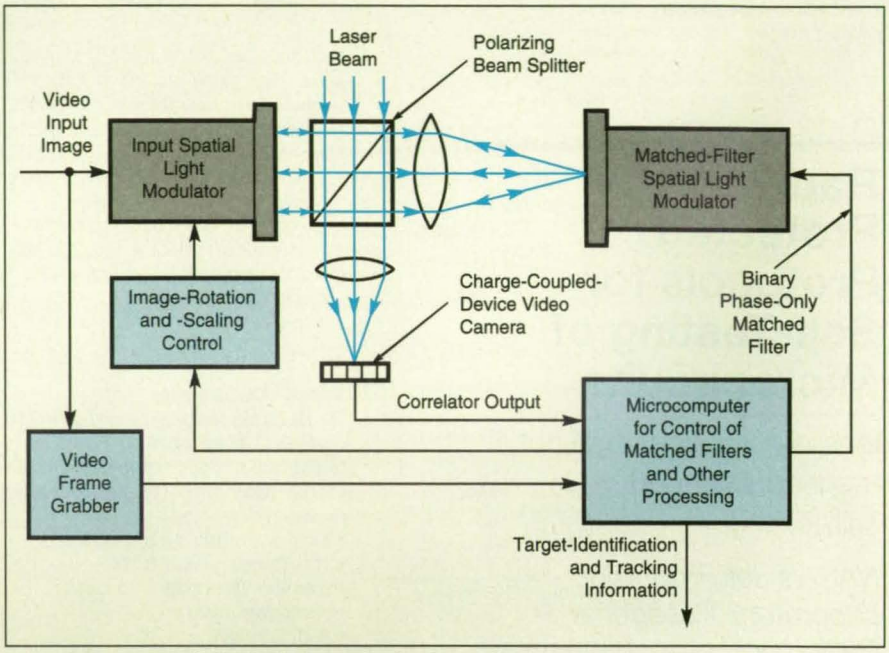
Infrared images of unknown targets would be correlated quickly with images of known targets.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed automatic target-recognition apparatus would consist mostly of a digital-electronic/optical cross-correlator that would process infrared images of targets. This apparatus (see figure) would incorporate some of the features of the correlator described in "Prototype Optical Correlator for Robotic Vision System" (NPO-18451), NASA Tech Briefs, Vol. 17, No. 3 (March 1993), page 42, and some of the features of the correlator described in "Compact Optical Correlator" (NPO-18473), Laser Tech Briefs, Vol. 1, No. 1 (September 1993), page 38. The apparatus might be useful in a robotic system; for example, to recognize and track such infrared-emitting, moving objects as variously shaped hot workpieces on a conveyor belt.

Like other developmental digital-electronic/optical cross-correlators, this one would offer the combined advantages of flexibility and adjustability plus rapid optical processing, in parallel, of data from all parts of the input image.

One of the advantages of a digital-electronic/optical cross-correlator is that a large number of known reference images (e.g., infrared images of hot workpieces of known size and shape) can be stored in memory. By the very nature of an optical cross-correlator, the input image can be cross-correlated with respect to all of the reference images simultaneously. Thus, if the input image matches that of any of the known targets, a match can be found quickly.



This **Proposed Digital-Electronic/Optical Correlator** would classify an unknown target depicted in the input image by performing a cross-correlation with reference images of many known targets simultaneously.

This work was done by Marija S. Scholl of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 98*** *on the TSP Request Card. NPO-18503*

Data-Acquisition System With Remotely Adjustable Amplifiers

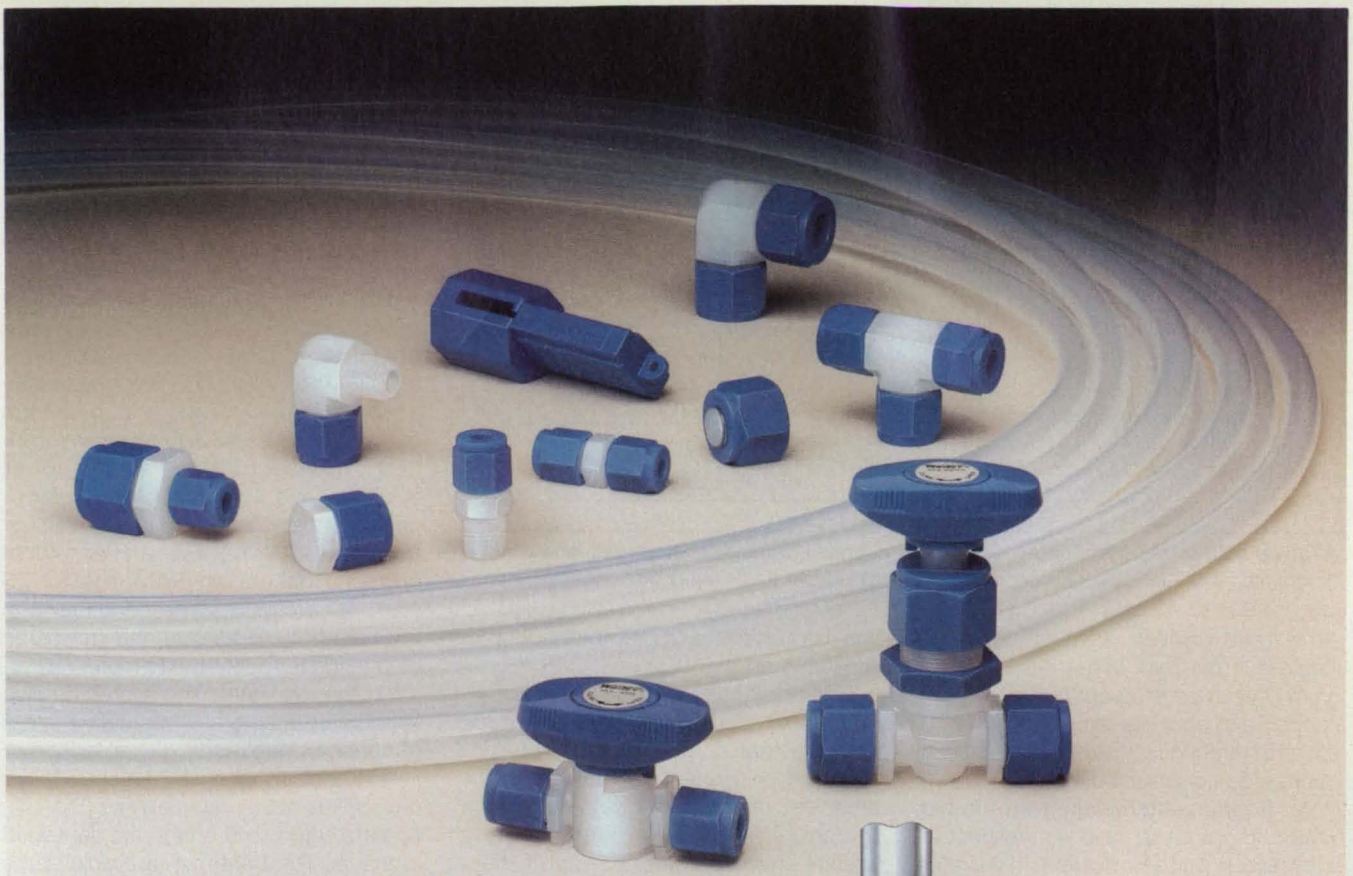
Operation, maintenance, calibration, and adjustment are standardized.

John F. Kennedy Space Center, Florida

An improved data-acquisition system that has both centralized and decentralized characteristics has been developed to update an obsolescent data-acquisition system at Kennedy Space Center. The system provides an infrastructure for automation and standardization of operation, maintenance, calibration, and adjustment of many transducers. In so doing, it also increases efficiency by reducing the need for a diminishing work force of highly trained technicians to perform routine tasks. Large industrial and academic laboratory facilities might also benefit from a system like this one.

The system features three principal technological developments. The first is that of the tag random-access memory (tag RAM). This is a nonvolatile RAM that effects electronic storage of all transducer information at the location of the transducer to prevent loss of information, reduce paperwork, and provide for remote electronic control of the transducer. A separate tag RAM is dedicated to each transducer and is connected directly to the transducer as part of a "pig-tail" cable adaptor. The tag RAM for each transducer is loaded, during calibration of the transducer, with all pertinent calibration and adjustment data. Each tag RAM features password protection to prevent inadvertent modification of data.

The second technological development is that of a self-programming amplifier called a universal signal-conditioning amplifier (USCA). Along with a tag RAM, a separate USCA is dedicated to each transducer and is connected to the transducer along with the tag



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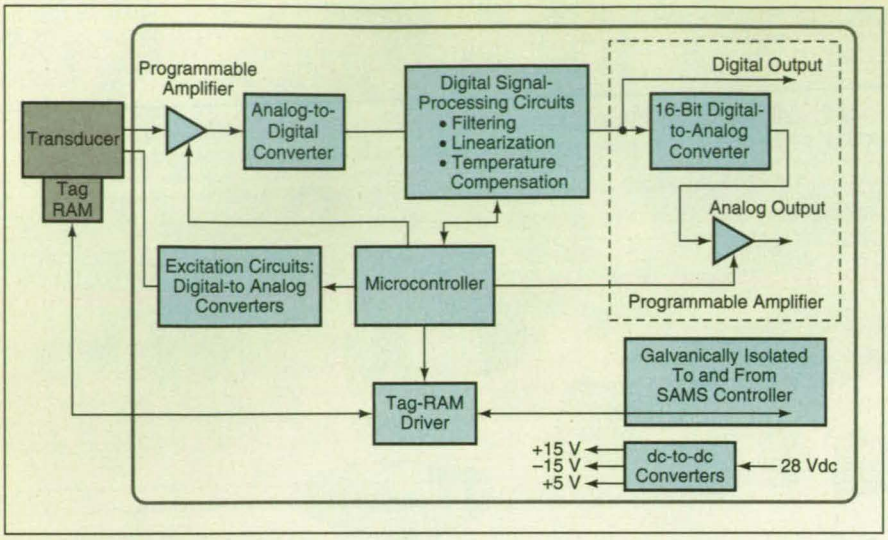


A **Universal Signal-Conditioning Amplifier** is a rugged, versatile unit with self- and remote-programming capabilities. It is connected with a transducer and a tag RAM.

RAM (see figure). A USCA can be installed in the field, is rugged, can program itself or be programmed by remote control, and supplies excitation (if needed) to the transducer. When the USCA is connected to a transducer with a tag RAM, it reads information from the tag RAM and programs itself with respect to excitation voltage or current, gain, output range, type of output (digital or analog), digital filter settings, and linearization (via curve fit by a polynomial of up to seventh order).

A microcontroller and digital signal-processing circuitry in the USCA provide flexibility that enables the use of nonstandard or unusual transducers in the otherwise standardized data-acquisition system. The USCA is contained in a special environmental housing. It measures its internal temperature and corrects its gain and offset to prevent degradation of data by ambient-temperature effects from −25 to +60 °C. All parameters for calibration of the amplifier can be loaded electronically into an internal nonvolatile RAM. The transducer inputs, digital and analog inputs and outputs, and power input are galvanically isolated from each other to prevent ground loops and to minimize damage from lightning and other transients.

The third development is that of a subsystem called the "self-aware measurement system (SAMS) controller." The SAMS controller resides in a centralized data-acquisition system and provides supervisory control, connect/disconnect status and time for all channels, and system information for all channels that contain tag RAMs alone or tag-RAM/USCA pairs. In a channel that contains only a tag RAM, the SAMS controller provides a host computer with the capability to identify and download all transducer-specific information located in the tag RAM. The system is also capable of putting any transducer into a remote-calibrate mode.

The addition of a USCA expands the capabilities of the data channel. The calibration, setup, and other data contained in the tag RAM are then available to the USCA. With modifications, they are also available to the SAMS controller. The

SAMS controller communicates bi-directionally with the USCA, enabling remote control and monitoring of such USCA functions as new filter settings or modified full-scale or offset ranges for special measurements with existing transducers. The SAMS controller can read the automatic USCA setup parameter and enables the SAMS operator to override any parameters.

This work was done by Mark A. Nurge and William E. Larson of **Kennedy Space Center** *and Carl G. Hallberg, Steven W. Thayer, Jeffrey C. Ake, Stuart M. Gleman, David L. Thompson, Pedro J. Medelius, Wayne A. Crawford, Richard M. VanGilder, Johnny L. Kerce, and Joey S. Fairbanks of I-NET, Inc. For further information,* ***write in 239*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Kennedy Space Center [see page 20]. Refer to KSC-11688.

Versatile Controller for CCD's

This circuit can control CCD's of various designs.

Goddard Space Flight Center, Greenbelt, Maryland

A general-purpose controller for a charge-coupled device (CCD) can be programmed to accommodate any of a variety of CCD designs. In the operation of the controller, software is used to specify the CCD-clock waveforms, which are thus available in great diversity. The controller includes a timing-signal generator controlled by a microcomputer. The flexibility and speed of the controller make it a versatile tool for laboratory testing and for a variety of applications.

The controller can operate existing CCD's and will be able to operate most CCD's expected to be developed in the foreseeable future. For example, it can handle either a large CCD array or a mosaic of smaller CCD's. It can operate in either an analog mode (long integration, slow readout) or in a photon-counting mode (fast, continuous readout).

The capability of the controller for adjustment of its speed, waveforms, and voltages via software is an important advantage for evaluating CCD's in the laboratory. It is especially important in space applications in which CCD's can be degraded by radiation but can be retuned to optimize their performances.

The microcomputer in the controller is a single-chip integrated circuit that receives commands from a host computer, issues instructions to the timing-signal generator, and loads CCD-clock waveforms into first-in/first-out (FIFO) memories (see figure). The timing-signal generator produces the requisite number of pulses at the desired frequency to clock out data from the FIFO memories; it consists of five independent counter/timers on a single chip; each counter/timer can be programmed to generate a repetitive square wave at a particular frequency and duty cycle or to count to a preset number, stop, and

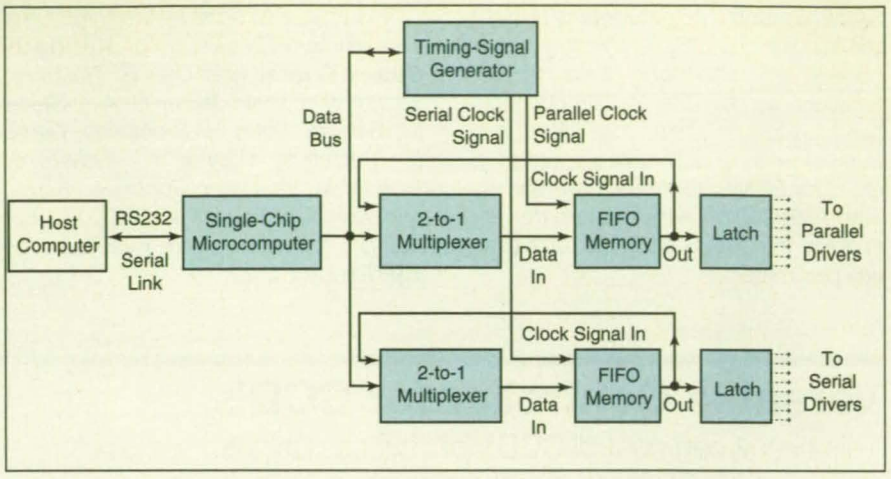
issue an interrupt to the microcomputer.

Each FIFO memory stores waveform sequences that govern the operation of a CCD. The output of a FIFO memory is connected back to its input. As soon as a byte at the head of a queue of waveform data has been clocked out of a FIFO memory by the timing-signal generator, it goes back to the input and propagates through, joining the end of the queue. The FIFO memory is thus operated as a circular storage device, and any byte sequence can be used over and over again.

One FIFO memory is used for parallel output, and two are used for serial output. The storage capacity of these FIFO memories is ample for currently available CCD's but can be expanded if necessary.

The use of circuitry separate from the microcomputer to clock out the waveforms ensures stability of the intervals between the readout of successive pixels. It is also important for keeping noise low by use of double correlated sampling. The clock speed of both parallel and serial operations can be much higher than that of the microcomputer.

Several microcomputers can be connected on a serial link to the host computer. The host can address a single microcomputer, a subgroup of microcomputers, or all microcomputers at once. A group of CCD's — each with its own microcomputer, FIFO memories, and timing generator — can therefore be controlled by the same host computer. A group of dissimilar CCD's each performing a different function — e.g., tracking, image-motion compensation, image correction, and scientific-data acquisition — can likewise be linked and controlled by a single host computer.



CCD Waveforms and Timing Instructions travel from the host computer to the microcomputer over a serial link. The microcomputer loads the commanded waveforms into the first-in/first-out memories and instructs the timing generator to clock out the waveform data.

This work was done by J. Novello of **Goddard Space Flight Center** *and P. C. Chen of Computer Sciences Corp. For further information,* ***write in 70*** *on the TSP Request Card.*
GSC-13269

Wavelength-Division Multiplexing of Bipolar Digital Signals

Pulses at two different wavelengths signify opposite polarities.

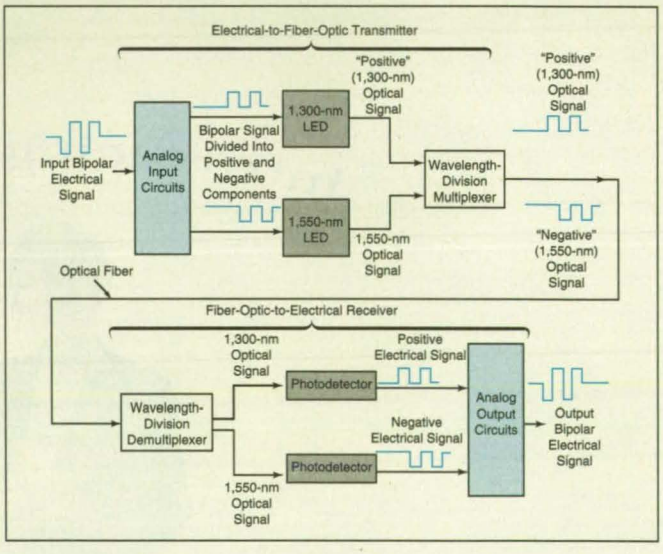
John F. Kennedy Space Center, Florida

In the system shown in the figure, bipolar digital data are transmitted by use of wavelength-division multiplexing on a single optical fiber. A bipolar digital signal can assume any of three levels: positive, zero, and negative. An electrical signal can be set at a corresponding positive, zero, or negative voltage, but the output of a light-emitting diode (LED) used to transmit digital data on an optical fiber can be set at only two levels: on and off.

Accordingly, in this system, two LED's of different wavelengths are used. Turning on one LED, which radiates at a wavelength of 1,300 nm, signifies "positive." Turning on the other LED, which radiates at 1,550 nm, signifies "negative." Leaving both LED's turned off signifies "zero."

At the transmitter, the incoming electrical bipolar digital signal is first applied to analog circuits that separate it into its positive and negative component pulses. Each component is used to modulate the output of the LED assigned to it. The outputs of the LED's are combined by a wavelength-division multiplexer at the input end of the optical fiber.

In the receiver, the signals coming out of the optical fiber at the two wavelengths are separated by a wavelength-division demultiplexer, and fed to separate photodetectors, which reconstruct the component positive and negative pulses. Analog output circuits combine these pulses, reconstructing the bipolar digital signal that was fed to the transmitter.



Two Different Wavelengths are used to transmit pulses that signify "positive" or "negative" bipolar digital data. The simultaneous absence of pulses at both wavelengths signifies digital "zero."

This work was done by Ronnie D. Gibbons and John L. Ubele II of Lockheed Space Operations Co. for **Kennedy Space Center.** *For further information,* ***write in 22*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Kennedy Space Center [see page 20]. Refer to KSC-11610.

Frequency-Shift Hearing Aid

The voice spectrum would be mapped to frequencies where the ear remains sensitive.

Langley Research Center, Hampton, Virginia

A proposed hearing aid would map the spectrum of speech into a band of lower frequencies at which the ear remains sensitive. The frequency range of normal human hearing extends to about 15,000 Hz, but most speech is contained in the frequency range from 100 to 5,000 Hz. With increasing age, people often lose sensitivity to higher frequencies (often above about 1,500 Hz). By redirecting normal speech frequencies into the frequency band from 100 to 1,500 Hz, the hearing aid would allow such people to understand normal conversation, including telephone calls, without excessive amplification. In contrast, conventional hearing aids amplify all or selected parts of the speech spectrum: in cases of severe loss of hearing, the required amplification may become impractically high, and the continued use of high amplification could damage the wearer's remaining hearing during the long term.

Speech information is transferred by fairly slow amplitude modulation and slowly changing frequency modulation of an acoustic carrier wave. The carrier frequency must be high enough so that ears and eardrums can detect the carrier wave efficiently. The information is contained in words that are transmitted at a rate of about 2 per second and have a basic content of about 100 pieces of information per word. The basic information only conveys which word is being spoken, and this does not depend on the precise carrier frequency. The word information can be transposed to a lower carrier frequency, much as a song can be sung in a lower pitch and still be understood.

The frequency-shift hearing aid would separate the amplitude and frequency modulated information content of a message from the normal speech carrier wave and use the information to modulate a carrier of lower frequency. The result would be a message at a lower carrier frequency but carrying information at the same rate. The carrier wave or the information modulation could be selectively clipped or filtered to suppress loud or distracting sounds.

While the highest frequencies must be shifted down considerably, the low to middle frequencies do not have to be changed much. At the same time, the frequency modulation portion of the speech signal must follow the same trends as the original speech to convey the information in the clearest way. This is probably best done with nonlinear mapping. For example, fout = 23(fin)1/2 – 130, where fout and fin are the output and input frequencies, respectively, in hertz. In this example, an input frequency of 100 Hz would stay the same, while an input frequency of 5,000 Hz would be shifted down to just under 1,500 Hz.

The principle of the operation of this hearing aid could be adapted to other uses as well. For example, it could be used to clear up noisy telephone or radio communication. In addition, loudspeakers could be more easily understood in the presence of high background noise.

This work was done by Leonard M. Weinstein of **Langley Research Center**. *No further documentation is available. LAR-15056*

Improvements in Optically Stimulated Electron Emission

OSEE can reveal contamination in many situations in which other techniques do not work.

Langley Research Center, Hampton, Virginia

Optically stimulated electron emission (OSEE) has been used by NASA in inspection for contamination of critical bonding surfaces in the solid rocket motors of the Space Shuttle prior to the formation of adhesive bonds on those surfaces during manufacture and refurbishment. The fundamental OSEE inspection technique was described in "Surface-Contamination Inspection Tool for Field Use" (MFS-25581), NASA Tech Briefs, Vol. 6, No. 2 (Summer 1981), page 190, and "Detecting Contamination With Photoelectron Emission" (MFS-25619), NASA Tech Briefs, Vol. 6, No. 3 (Fall/Winter 1981), page 307. This technique involves measurement of photoelectrons released from a substrate under ultraviolet irradiation. OSEE measurements have been shown to be sensitive to contaminants in amounts that, while large enough to weaken bonds, are too small to be visible to the naked eye.

The OSEE technique is also applicable to roughened surfaces, for which many optical techniques cannot be used. The OSEE measurement head is easily portable, and the measurement operation is convenient and rapid, making OSEE a useful inspection technique in the industrial environment. OSEE has proved useful enough that further development has been undertaken to increase the precision and stability of the measurements. Work has also been done to extend the applicability of OSEE measurements to nonconducting substrates.

Improvements being implemented include a change in the geometry of the measurement volume so that the electric field lines are parallel within the illuminated region, which itself is limited with both apertures and focusing optics. The primary OSEE-generating spectral line of the ultraviolet lamp has been identified, and the radiation of that line from the lamp is independently measured and used to control lamp current to increase stability. The interfering effects associated with oxygen and water vapor in the measurement region are being eliminated from measurement by use of a purge gas. The lamp is further environmentally isolated and subjected to constant cooling to increase stability and optimize OSEE-producing radiation.

Further improvements in the measurement have been identified. A laboratory prototype of a Kelvin Probe, capable of measuring surface work functions in metals, has been constructed and shown to be an appropriate complement to the basic OSEE apparatus for inspecting surfaces, the work functions of which vary naturally. In addition, external control of the collector bias voltage has made it possible to obtain reproducible OSEE measurements on nonconducting surfaces by using the measurement head to replace the electrons removed following a measurement. (The procedure is called "charge replacement.")

With these improvements and extensions, OSEE should become useful in a number of industrial processes in which inspection to detect contamination would be highly useful. In such processes, no suitable contamination-inspection technique has been available.

This work was done by William T. Yost of **Langley Research Center**, *Christopher S. Welch of the College of William and Mary, and Edmond J. Joe and Bill B. Hefner, Jr., of Analytical Services and Materials, Inc., with cooperation from Personnel from Marshall Space Flight Center. No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-15063.

Fatigue-Crack-Tip Locator

Fatigue experiments can be run continuously under automated monitoring.

Langley Research Center, Hampton, Virginia

Figure 1 schematically illustrates part of a fatigue-testing system that includes an automated subsystem that continuously tracks the location of the fatigue-crack tip in a metal or other highly electrically conductive specimen. The fatigue-crack-tip-locating subsystem can also search the specimen to find the initial fatigue crack and its tip and to trace out hidden fatigue cracks and other flaws inside the specimen.

The fatigue-crack-tip-locating subsystem operates under the overall control of a personal computer, which also controls the load frame that applies the prescribed cyclic stresses to the specimen. An electromagnetic flaw detector based on the eddy-current principle is scanned over a surface of the specimen by x- and y-axis stepping-motor drives controlled by the computer. [The electromagnetic flaw detector was described previously in "Electromagnetic Flaw Detector Is Easier To Use" (LAR-15046), NASA Tech Briefs, Vol. 18, No. 7 (July 1994), page 36. To recapitulate: the electromagnetic flaw detector is a novel eddy-current probe that puts out a single, unambiguous ac voltage indicative of flaws in the specimen.]

The automated search for the fatigue crack and its tip is feasible because of the unambiguous flaw signal provided by the probe. The top part of Figure 2 shows the output signal of the probe as it is scanned across two fatigue cracks in an aluminum-alloy specimen. The large peak in the output voltage of the probe occurs when the probe is centered

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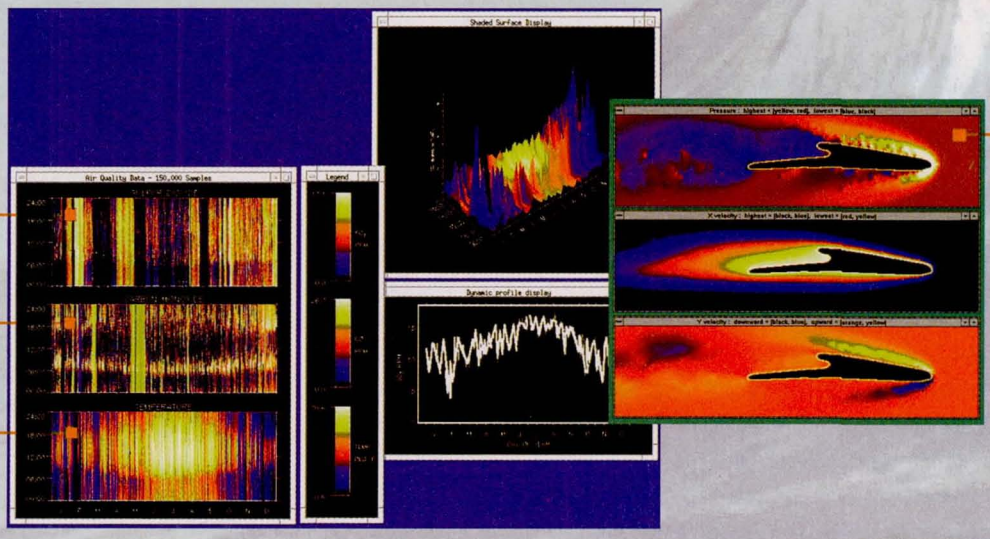

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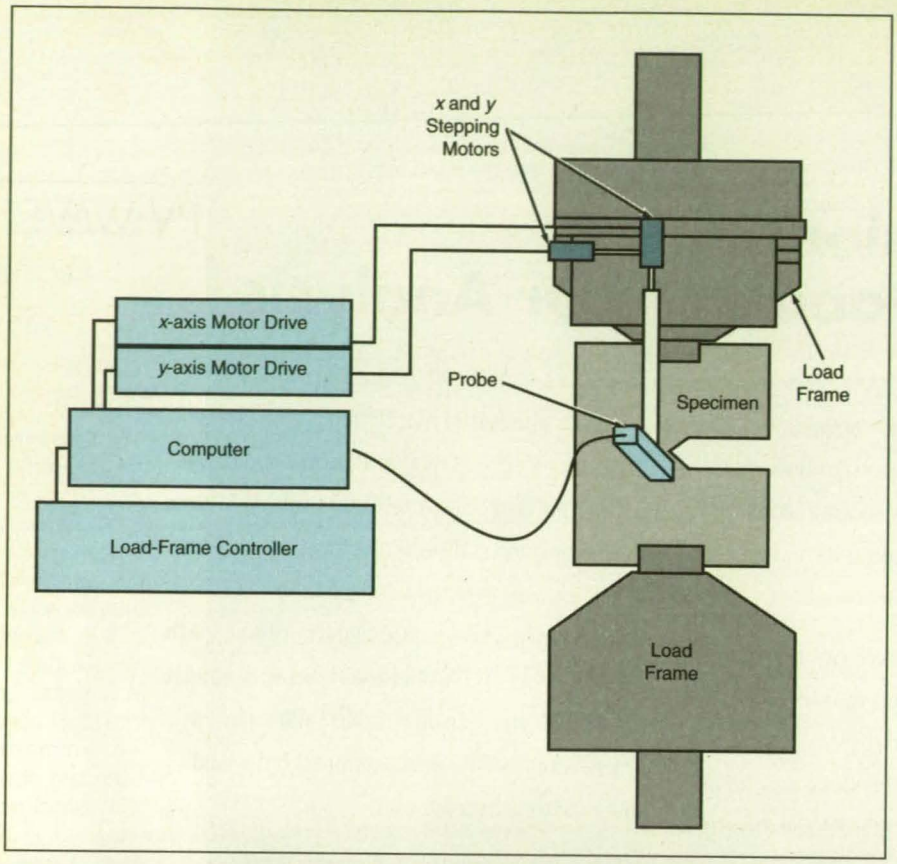


Figure 1. The **Fatigue-Crack-Tip Locator** is a subsystem of a fatigue-testing system. The probe is scanned across the specimen to locate the tip of the fatigue crack.

over the fatigue crack.

When the probe is scanned along a crack, its output peaks at the crack tip. This is illustrated in the lower part of Figure 2, which is a plot of probe output as a function of position on an aluminum-alloy plate specimen with fatigue cracks emanating from a drilled central hole. The probe-output level rises sharply at the location of the hole and stays relatively constant around the circumference of the hole. The two fatigue cracks grown from the hole are easily detected as protrusions from the otherwise circular pattern. In addition, the output level peaks at the outer tips of both fatigue cracks. Scanning outward along each crack, the output level falls sharply from the peak to the background level as the probe passes the crack tip.

Thus, a computer peak-search routine is used to locate the tip of a growing crack. Thereafter, the position of the probe is incremented in the direction of crack growth, as determined by previous locations of the crack tip, and the scan is repeated until the new crack-tip location is found. After locating the new crack tip, the probe is moved a short distance back along the crack and the search repeated. By continuously reevaluating the path of the crack near the crack tip, crack-tip-location errors caused by noise and crack branching are avoided.

During a typical fatigue experiment, a fatigue crack grows to predetermined lengths at which load levels and/or other parameters of operation of the load frame must be adjusted. Inasmuch as the computer has traced the growth of the crack from initiation, it can automatically adjust the load-frame controls when the crack reaches these predetermined lengths.

Thus, the fatigue-crack-tip locating system provides for automated control and monitoring of fatigue experiments, saving time for researchers and enabling experiments to run unattended 24 hours a day. In addition, all information on crack-tip trajectories and rates of growth of cracks is recorded automatically, so that researchers have access to more information than is available from conventional, nonautomated monitoring.

This work was done by Min Namkung and C. Gerald Clendenin of **Langley Research Center,** *Buzz Wincheski, James P. Fulton, and Ronald G. Todhunter of Analytical Services and Materials, Inc., and John W. Simpson of Lockheed Engineering & Sciences Co. For further information,* ***write in 184*** *on the TSP Request Card.*

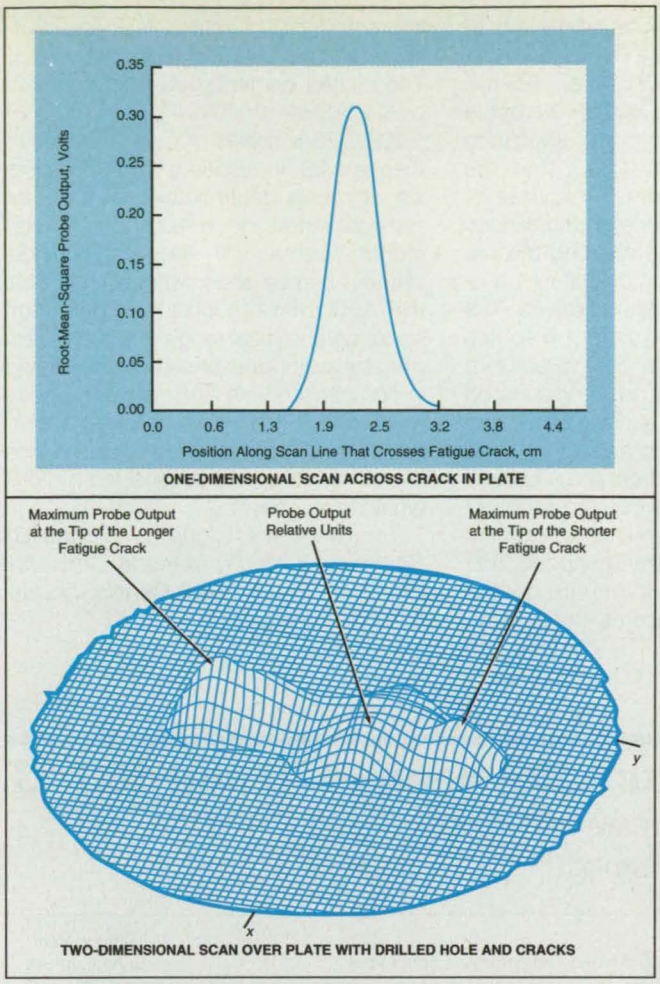


Figure 2. The **Probe Output** peaks as the probe is scanned across two fatigue cracks, and the peak is highest at the tip of the crack.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-15085.

Preparation and Analysis of Specimens of Ablative Materials

Inductively-coupled-plasma/atomic-emission spectroscopy is much faster than is atomic absorption spectroscopy.

Marshall Space Flight Center, Alabama

A procedure for chemical analysis of specimens of the silicone-based ablative thermal-insulation materials SLA-561 and MA25 involves acid digestion of the specimens to prepare them for analysis by inductively-coupled-plasma/atomic-emission spectroscopy (ICP/AES). In comparison with an older procedure in which atomic-absorption spectroscopy (AAS) was used, this procedure offers advantages including, primarily, that ICP/AES is faster and more accurate than AAS is. The results of such analyses can be stored in a data base, used to trace variations in concentrations of chemical elements in

materials during long-term storage, and used in a timely manner in investigations of failures. The acid-digestion portion of the procedure can be applied to other thermal-insulation materials that contain room-temperature-vulcanizing silicones and enables instrumental analysis of these materials.

Super Lightweight Ablator (SLA) is a composite of cured silicone resins highly filled with cork particles, small silica spheres, silica fibers, and phenolic microballoons. SLA is the primary ablative material on the external tank of the Space Shuttle. MA25 is similar to SLA-561 but does not contain cork or phenolic microballoons. Previously, the preparation of specimens of these materials for analysis included ashing in a muffle furnace, overnight cooling, and 10 h of acid digestion. The high temperatures involved in the ashing process sometimes caused loss of critical elements.

The present acid-digestion process begins with the addition of 15 mL of fuming sulfuric acid to a 0.5-g specimen of SLA-561 or MA25 in a 125-mL polytetrafluoroethylene bottle. The bottle and the mixture of acid and specimen are heated for 2 h at 125°C; then the bottle is removed from the source of heat, and 5 mL of concentrated sulfuric acid are added. The bottle and mixture are then heated for approximately 1 h or until all solid particles are dissolved. The bottle is then removed from the source of heat and allowed to cool to ambient temperature. Five mL of concentrated nitric acid are added, and the bottle and its contents are heated again for 1 h at 125°C, then removed from the source of heat and allowed to cool to ambient temperature. Next, 2 mL of 48 percent hydrofluoric acid is carefully added, and the bottle and its contents are heated until the contents become translucent; this takes about 2 h. The contents are then transferred to a 100-mL polytetrafluoroethylene volumetric flask and diluted to volume with demineralized water. The diluted contents are then analyzed by ICP/AES.

ICP/AES is orders of magnitude faster than is AAS. In addition, ICP/AES offers simultaneous determination of the relative concentrations of more than 40 elements, whereas with AAS, only a single element can be analyzed at a time. Also ICP/AES offers much lower detection limits, an analytical range of three orders of magnitude, and limited matrix effects in comparison with AAS. A single specimen of SLA-561 or MA25 can be analyzed by ICP/AES for 15 elements in less than 5 minutes; such an analysis by AAS would take 2 days.

This work was done by William C. Solomon of Martin Marietta Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-28807

Apparatus Regulates Temperature Between –170 and 100 °C

Temperature pulses are smoothed out by thermal mass and mixing.

NASA's Jet Propulsion Laboratory, Pasadena, California

Figure 1 illustrates schematically an apparatus that provides a flow of nitrogen at a regulated temperature. It is designed to maintain the temperature of a laboratory instrument or a small environmental test chamber within ±2 °C of a set point that lies between –170 and 100 °C. In comparison with other cryogenic apparatuses that regulate temperatures in the same range with similar precision, this one is relatively inexpensive, in large part because it is made of commercially available items, including temperature-control circuits, standard plumbing parts, and stock materials.

The present apparatus was preceded by one in which hot gaseous nitrogen and cold liquid nitrogen were alternately pulsed into a feed line. Frequently, this predecessor apparatus produced overcooling temperature excursions: even short pulses of liquid nitrogen often caused the temperature to fall below the set point by an unexpectedly large amount. The present apparatus also uses gaseous and liquid nitrogen, but incorporates several features that suppress large temperature fluctuations.

The apparatus is fed from liquid- and gaseous-nitrogen manifolds. Thermocouples connected to the temperature-control circuits measure temperatures at selected locations along the flow path of the outflowing nitrogen mixture and in the instrument that is to be maintained at the desired temperature. The

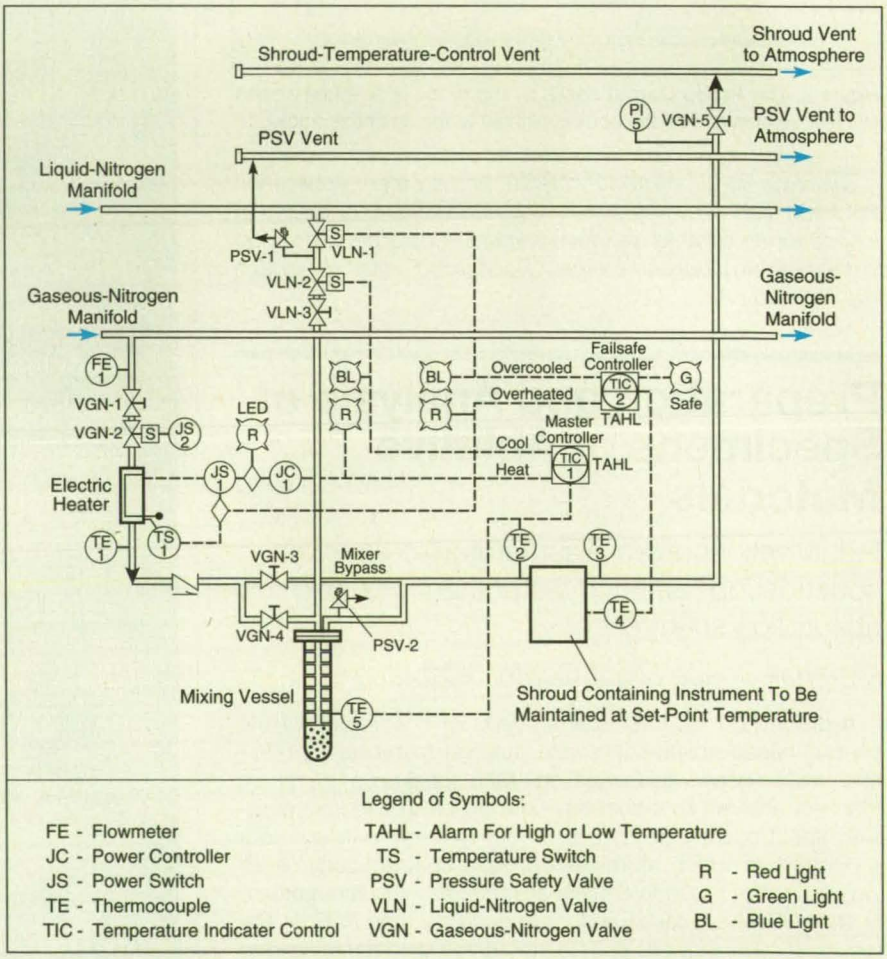


Figure 1. This **Temperature-Control Apparatus** mixes pulses of liquid nitrogen into smoothly flowing nitrogen gas to produce a flow of nitrogen gas at a controlled low temperature.

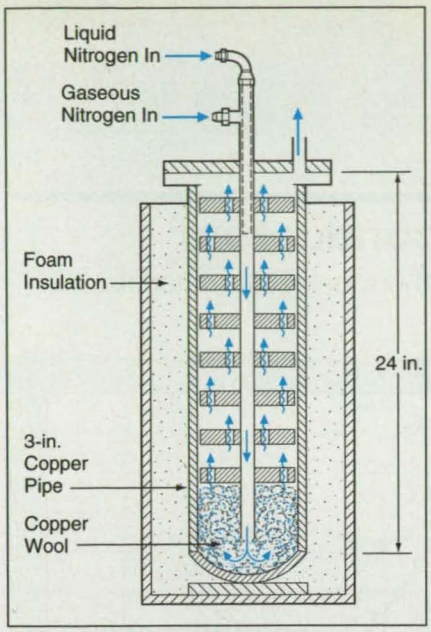


Figure 2. The **Mixing Chamber** provides turbulence, thermal mass, and thermal conductance to promote thermal and mechanical mixing of the liquid and gaseous flows and thereby suppresses large transient deviations from the set-point temperature.

flow of gaseous nitrogen is continuously measured and is manually adjustable. If the set-point temperature exceeds the ambient temperature, this gaseous flow is heated as necessary to raise the outflow temperature. If the set-point temperature lies below the ambient temperature, then pulses of liquid nitrogen are added as needed to lower the outflow temperature.

An important part of the apparatus is a mixing vessel (see Figure 2) that is specially designed to satisfy the following criteria: (1) It must be thermally massive enough to suppress the temperature excursions caused by pulsing the liquid nitrogen, but not so massive as to make the overall temperature-control feedback response unacceptably sluggish; (2) the thermal mass must be configured for rapid transfer of heat from the gaseous to the liquid nitrogen; (3) the pressure drop in flow through the vessel must be acceptably small; and (4) the vessel must be as simple and cheap as possible.

The containment wall of the vessel is made from 3-in. (7.6-cm) copper pipe mounted in foam insulation. Flows of liquid and gaseous nitrogen enter the vessel through concentric copper tubes and first make contact with each other at the outlet of the inner concentric tube, part way down the outer concentric tube. The mixture emerges from the outer tube at the bottom of the vessel; there, the mixture impinges on a bed of copper wool, which enhances mixing by providing a combination of turbulence, thermal mass, and thermal conductivity. The mixture then flows back up, past a series of copper baffles, to an eccentric outlet at the top of the vessel. The baffles provide additional thermal mass, and the holes in the baffles are positioned to enforce a weaving flow pattern that enhances the transfer of heat between the flowing nitrogen and the copper thermal masses.

This work was done by Kenneth R. Johnson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 255*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL [see page 20]. Refer to NPO-18995.

An author's name was omitted from a brief appearing in the Physical Sciences section of the October 1994 issue. The brief entitled "Measurement of Crossflow Vortex Structure," which appeared on page 75, should have credited both Navel K. Agarwal of Analytical Services and Materials, Inc. and Dal. V. Maddelon of Langley Research Center.

High-Performance Thermoelectric Semiconductors

Figures of merit are almost double those of current state-of-the-art thermoelectric materials.

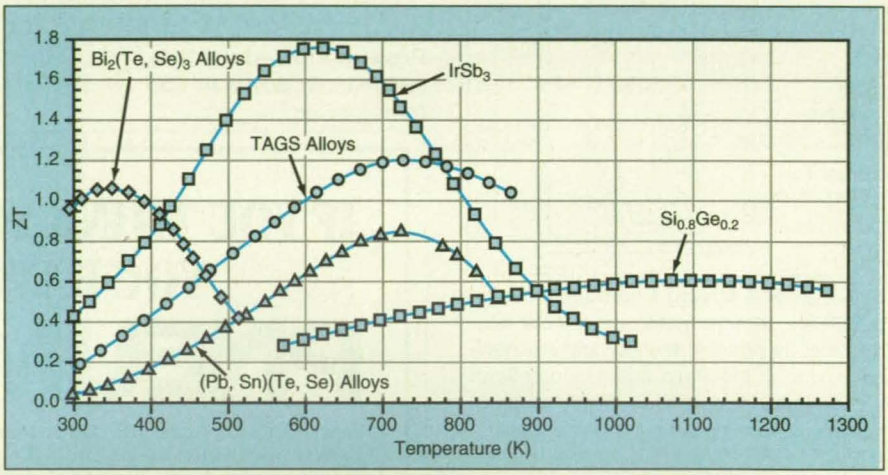
NASA's Jet Propulsion Laboratory, Pasadena, California

$IrSb_3$ is a semiconductor that has been found to exhibit exceptional thermoelectric properties. $CoSb_3$ and $RhSb_3$ have the same skutterudite crystallographic structure as that of $IrSb_3$, and they exhibit exceptional transport properties that are expected to contribute to high thermoelectric performance. These three compounds form solid solutions (alloys with compositions of $Ir_{1-x-y}Rh_xCo_ySb_3$). This combination of properties offers potential for the development of new high-performance thermoelectric materials for more efficient thermoelectric power generators, coolers, and detectors.

The dimensionless figure of merit for the thermoelectric performance of a material at a given temperature is called "*ZT*" and is given by

$$ZT = \frac{S^2T}{\rho\lambda}$$

where T is the absolute temperature, S is the Seebeck coefficient (the ratio between the electrical-potential and temperature gradients), ρ is the electrical resistivity, and λ is the thermal conductivity. A combination of theoretical and experimental efforts has resulted in optimization of p-type specimens of $IrSb_3$. In particular, at a dopant concentration of 7×10^{18} cm^{-3}, an experimental maximum *ZT* of nearly 1.8 was observed at a temperature of about 350 °C: This is about 80 percent higher than the *ZT* values of other p-type materials now in use (see figure). Even greater values of *ZT* are predicted for $Co_{1-x-y}Rh_xIr_ySb_3$ alloys because the thermal conductivities of these alloys are less than that of $IrSb_3$.



The **Dimensionless Figure of Merit, *ZT***, as a function of temperature is plotted for optimized p-type $IrSb_3$ and for other state-of-the-art p-type thermoelectric materials.

In one potential application, p-type $IrSb_3$ stages would be incorporated, along with n-type $Si_{0.8}Ge_{0.2}$, into a radioisotope thermoelectric generator that would operate in the temperature range of 200 to 900 °C. The combined thermoelectric properties of $IrSb_3$ and $Si_{0.8}Ge_{0.2}$ would yield an energy-conversion efficiency of more than 13 percent — about 70 percent higher than that of an existing radioisotope thermoelectric generator that contains $Si_{0.8}Ge_{0.2}$ (only). The increase in efficiency would increase specific power of the generator from the present value of 5.6 W/kg to more than 10 W/kg. The enhanced thermoelectric performances of $IrSb_3$ and the $Ir_{1-x-y}Rh_xCo_ySb_3$ alloys could also be utilized in other applications such as waste heat recovery systems.

This work was done by Jean-Pierre Fleurial, Thierry Caillat, and Alexander Borshchevsky of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 126*** *on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

William T. Callaghan, Manager
Technology Commercialization
JPL-301-350
4800 Oak Grove Drive
Pasadena, CA 91109

Refer to NPO-19233, volume and number of this NASA Tech Briefs *issue, and the page number.*

Phenylethynyl-Terminated Polyimides

Molecular weights can be selected to obtain desirable properties.

Langley Research Center, Hampton, Virginia

Phenylethynyl-terminated polyimides exhibit properties that are suitable for films, moldings, adhesives, and composite-material matrices. These polyimides can be synthesized at various molecular weights, which can be selected to obtain desirable properties for specific applications.

Polyimides are condensation polymers that can be synthesized by various routes. The most popular route involves the reaction of an aromatic dianhydride with an aromatic diamine to obtain a polyamide acid as an intermediate product. The polyamide acid is either thermally or chemically cyclodehydrated to form the polyimide, which has a repeat unit of the general type where Ar is a tetravalent

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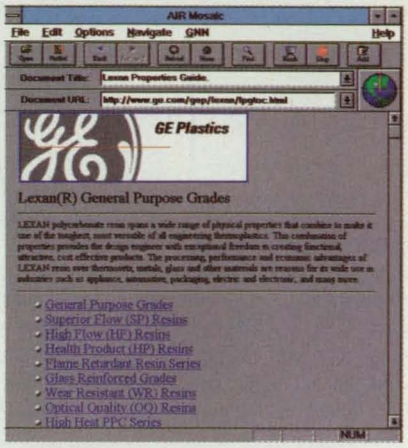

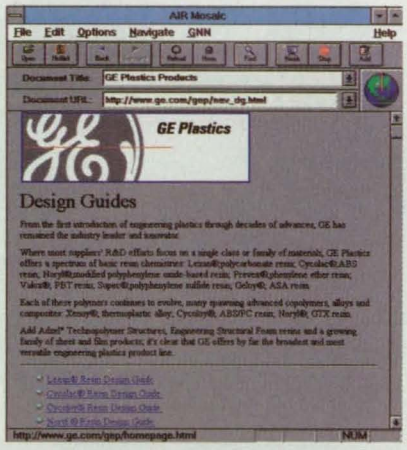

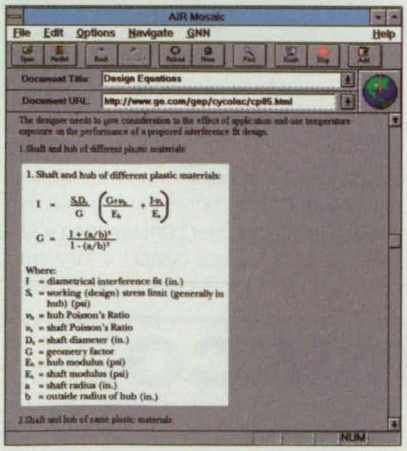

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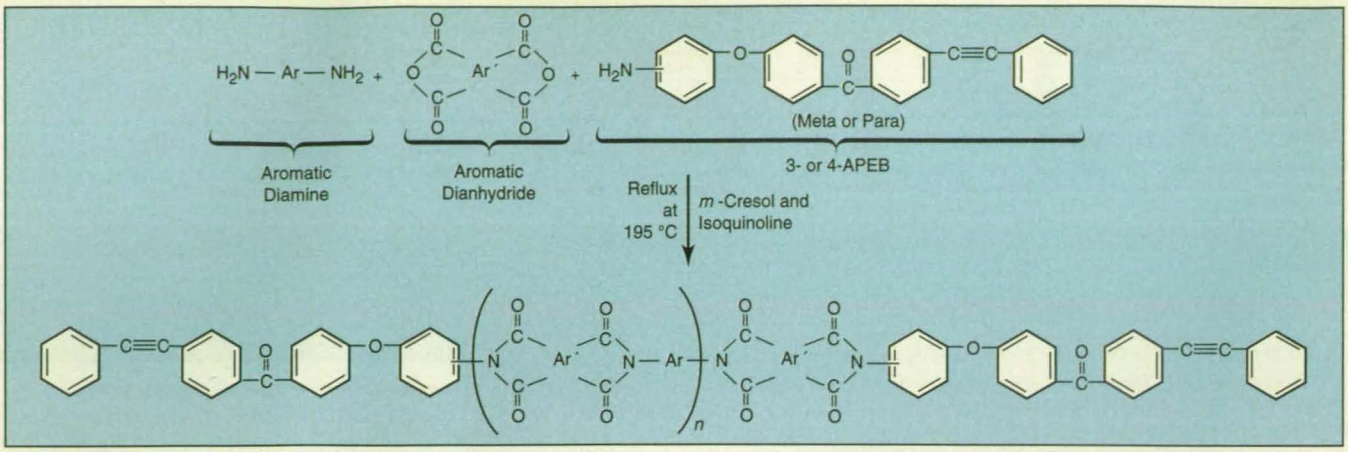
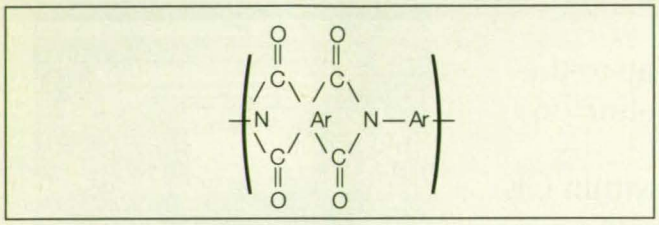


A **Phenylethynyl-Terminated Polyimide** is synthesized by reaction of an aromatic diamine with an aromatic dianhydride, along with 3- or 4-APEB, which reacts with the other ingredients to end-cap the oligomers.



aromatic radical and Ar′ is a divalent aromatic radical. A phenylethynyl-terminated polyimide is synthesized similarly, except that 3- or 4-aminophenoxy-4′-phenylethynylbenzophenone (3- or 4-APEB) is added to the other ingredients to end-cap the oligomers. The average molecular weight of the phenylethynyl-terminated polyimide can be obtained at any value within a wide range (about 500 to about 20,000 g/mole) by formulating the reaction mixture to include calculated, slightly unequal amounts of the monomers (the aromatic dianhydride and the aromatic diamine) and an appropriate amount of 3- or 4-APEB.

Prior to curing, low-molecular-weight phenylethynyl-terminated polyimides have low melt viscosities and can readily be processed into composites and adhesive bonds. When cured, phenylethynyl-terminated polyimides of different molecular weights display different properties. For example, low-molecular-weight phenylethynyl-terminated polyimides exhibit cross-link densities greater than those of high-molecular-weight phenylethynyl-terminated polyimides. High cross-link density normally results in greater resistance to solvents, higher modulus of elasticity, better high-temperature properties, and lower toughness than do low cross-link-density materials. Thus, the polymers can be designed to have the proper combination of properties for the desired application by controlling their molecular weights.

Unlike linear polyimides, phenylethynyl-terminated polyimides can be thermally cured to form cross-linked molecular structures typically increasing resistance to solvents, glass-transition temperatures, and moduli of elasticity. The advantage of phenylethynyl-terminated polyimides over polyimides containing pendent ethynyl groups is that the phenylethynyl-terminated polyimides can have low molecular weights and, therefore, low melt viscosities for easier processing into composites and adhesive bonds. The cross-link densities of phenylethynyl-terminated polyimides can be varied by changing the molecular weights of the oligomers. The low-molecular-weight versions (~< 6,000 g/mole) typically form brittle films, while the higher-molecular-weight versions (~> 6,000 g/mole) can form tough, creasible films. Furthermore, the cross-link densities of the cured phenylethynyl-terminated polyimides are chosen by selection of the molecular weights; low molecular weights lead to high cross-link densities.

The advantage of phenylethynyl-terminated polyimides over ethynyl-terminated polyimides is the higher reaction temperature of the phenylethynyl group compared to the ethynyl group. The phenylethynyl group begins to react at a temperature about 350°C, compared to about 200°C for the ethynyl group. This higher reaction temperature provides a larger temperature range to melt-process these polymers, whereas ethynyl-terminated polymers begin to react and, therefore, are either not melt processible or have a very small temperature range for melt processing. Most polyimides have glass-transition temperatures greater than 200°C, so that there is virtually no or a very narrow temperature range of melt processibility for ethynyl-terminated polyimides.

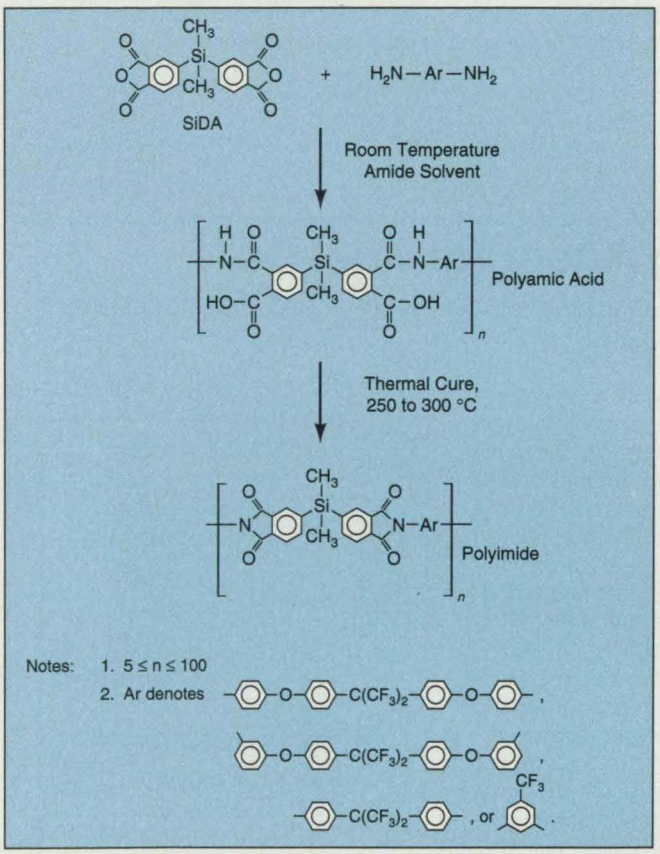
This work was done by Brian J. Jensen, Robert G. Bryant, and Paul M. Hergenrother of **Langley Research Center.** *For further information,* ***write in 58*** *on the TSP Request Card. LAR-15045*

Aromatic Polyimides With Low Dielectric Constants

These polyimides are also highly transparent.

Langley Research Center, Hampton, Virginia

An effort to develop improved dielectric film and coating materials has yielded linear aromatic polyimides that contain dimethylsilane linkages in the dianhydride portions of the molecules and at least one trifluoromethyl group in each of the diamine portions. Like other polyimides, these offer advantages of thermal stability, low density, resistance to ionizing radiation, toughness, and flexibility. In comparison with other polyimides that are now commercially available, these polyimides exhibit lower dielectric constants, which are advantageous as dielectric films in electronic circuits. Also in comparison with commercial polyimides (which are generally bright yellow), these polyimides are nearly transparent and colorless — an advantage in protective coating of solar photovoltaic cells, optical components, and antennas.



A **Linear Polyimide With a Low Dielectric Constant** is synthesized in reactions that incorporate dimethylsilane linkages in the dianhydride portions and at least one trifluoromethyl group in the diamine portions.

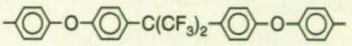
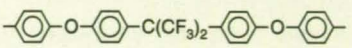
The synthesis of a polyimide of this type (see figure) begins with a polymer-grade dianhydride that contains dimethylsilane (SiDA) and an equimolar quantity of a polymer-grade aromatic diamine that contains a trifluoromethyl group. These two ingredients are combined in an amide solvent, and the mixture is stirred at room temperature in a closed vessel until a high-molecular-weight polyamic acid is formed. The solution of polyamide acid in solvent is applied to a substrate to form a thin surface film, which is then thermally converted to the polyimide by heating it to a temperature between 250 and 300 °C.

The table shows some of the properties of representative

polymers of this type, along with the corresponding properties of the commercial polyimide film Kapton H®. The silicon and fluorine atoms incorporated into these polyimides yield significantly lower dielectric constants. These polyimides are also significantly clearer, as shown in spectroscopic measurements on film specimens 0.5 mil (about 13 μm) thick at a wavelength of 500 nm. Each of the specimens of these polyimides was found to be at least 90 percent transparent, while the Kapton® specimen was found to be only 30 percent transparent.

This work was done by Anne K. St. Clair and Terry L. St. Clair of **Langley Research Center** *and J. Richard Pratt of PRC Kentron. For further information,* **write in 271** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,093,453). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14198.

Abbreviated Name of Polymer	Diamine Ar	Physical Appearance (1 mil Thick)	Dielectric Constant at 10 GHz
SiDA + 4, 4'-6F		Essentially Colorless	2.64
SiDA + 4-BDAF		Very Pale Yellow	2.56
SiDA + 3-BDAF		Pale Yellow/ Colorless	2.66
SiDA + DABTF		Pale Yellow/ Colorless	2.75
Kapton®	—	Bright Yellow	3.20

Dielectric Constants of polyimides like those illustrated generically in Figure 1 tend to range approximately from 2.5 to about 2.8, whereas those of older commercial polyimides tend to range approximately from 3.2 to 4.0, exact values depending on moisture contents.

Stable, Electroinactive Wetting Agent for Fuel Cells

Perfluorooctanesulfonic acid can be used with gas-diffusion electrodes in liquid-feed fuel cells.

NASA's Jet Propulsion Laboratory, Pasadena, California

Straight-chain perfluorooctanesulfonic acid (C_8 acid) has been identified as an innocuous and stable wetting agent for use with polytetrafluoroethylene-containing electrodes in liquid-feed direct-oxidation fuel cells like those suggested for use in vehicles and portable power supplies. C_8 acid in small concentrations (0.001 to 0.1 M) in aqueous liquid solutions of methanol, trimethoxymethane, dimethoxymethane, and trioxane enables the oxidation of these substances by use of commercially available electrodes of the type designed originally for use with gases. This useful function is specific to the C_8 acid molecule and is not achieved by other related perfluoroalkanesulfonic acids.

Electrodes used in fuel cells usually include metal catalyst powders that are either unsupported or supported by carbon and are mixed with polytetrafluoroethylene (which serves as a binder) and applied to polytetrafluoroethylene-containing carbon-paper substrates. Electrodes of this type that contain 15 to 50 percent of polytetrafluoroethylene are commercially available and are used in hydrogen/oxygen fuel cells in which the fuel and oxidant are supplied as gases. The large quantities of polytetrafluoroethylene in these cells are essential to the creation of uniform thin layers of the electrocatalysts on the substrates. When aqueous solutions of methanol and other water-soluble oxygenates are used in liquid-feed direct-oxidation fuel cells, the commercially available fuel-cell electrodes are unsuitable because they are not wetted adequately by the fuel solutions. A wetting agent is necessary so that the electroactive materials will make the good contact with the electrode, as is necessary for oxidation of the fuels in the solutions. The wetting agent of choice must decrease the interfacial tension without hindering the desired oxidation reaction by being specifically adsorbed on the electrodes.

The adsorption behavior of C_8 acid has been studied by cyclic voltammetry in sulfuric acid aqueous solutions with platinum electrodes. The double-layer capacitance of the Pt/sulfuric acid interface, as determined from the slope of the current-scan-rate plot in the electric-potential range of 0.4 to 0.6 V, is not affected by the presence of C_8 acid, as can be seen in Figure 1. The absence of any new peaks in the cyclic voltammogram shows that C_8 acid is not electroactive and that it is stable to electro-oxidation in the potential range of 0.0 to –1.30 V vs. NHE. The cyclic voltammograms for Pt/sulfuric acid in methanolic solutions with and without C_8 acid show that the kinetics of oxidation of methanol at the platinum electrode are unaffected by the presence of C_8 acid. The nonadsorbing nature of the perfluorooctanesulfonic acid anion is due to its low nucleophilicity and the strong electron-withdrawing nature of the fluorine substituents.

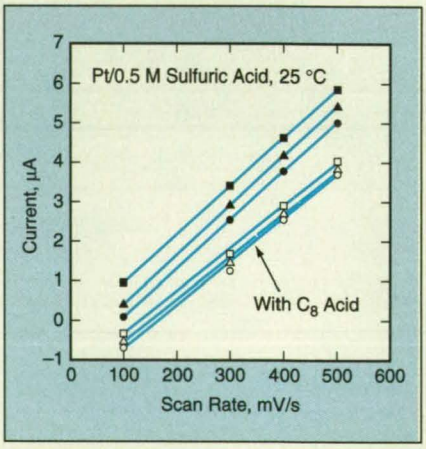


Figure 1. The **Slopes of These Plots**, which are derived from cyclic voltammograms, are proportional to the double-layer capacitance of the Pt/sulfuric acid interface.

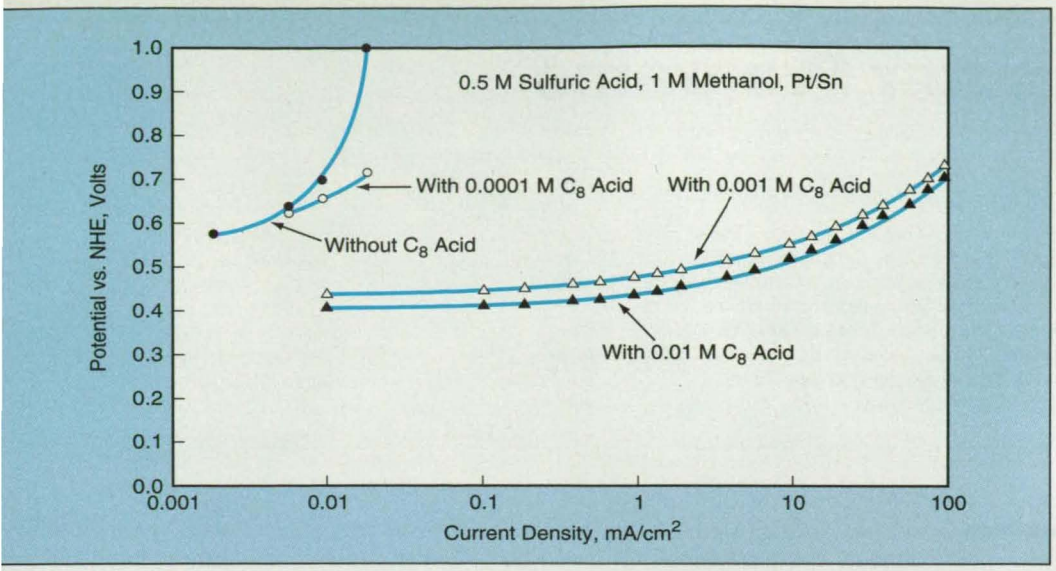


Figure 2. The **Wetting Action** of perfluorooctanesulfonic acid is indicated by the reduction of polarization during the electrooxidation of methanol.

The wetting action of C_8 acid has been demonstrated in half-cell experiments in which polytetrafluoroethylene-containing, high-surface-area, carbon-supported platinum and platinum-alloy electrodes were used. Figure 2 shows the effect of the concentration of C_8 acid on the kinetics of the oxidation of methanol at Pt/Sn electrodes in sulfuric acid electrolyte. The oxidation of methanol has also been carried out in 0.1 M pure C_8 acid solutions (no sulfuric acid), and the polarization curves indicate that the kinetics are unaffected by the presence of the perfluorooctanesulfonate ion.

This work was done by Surya G. Prakash, George A. Olah, Sekharipuram R. Narayanan, Subbarao Surampudi, and Gerald Halpert of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 262*** *on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Computer Programs

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Mathematics and Information Sciences

Decision-Tree Program

IND offers capabilities useful to both nonexpert and expert users.

A common approach to supervised classification and prediction in artificial intelligence and statistical pattern recognition involves the use of decision trees. A tree is "grown" from data by use of a recursive partitioning algorithm. The tree thus created yields good predictions of classes on new data. Standard algorithms are CART (by Breiman, Friedman, Olshen, and Stone) and ID3 and its successor C4 (by Quinlan). In addition to reimplementing parts of these algorithms and offering experimental control suites, the IND computer program also introduces Bayesian and Markov/ maximum-likelihood (MML) methods and more-sophisticated methods of searching in growing trees. These methods produce more-accurate class-probability estimates that are important in applications like diagnosis.

IND is applicable to most sets of data that consist of independent instances, each described by a fixed-length vector of attribute values. An attribute value can be a number or one of a set of attribute-specific symbols, or it can be omitted. One of the attributes is delegated the "target," and IND grows trees to predict the target. Prediction can then be done on new data, or the decision tree can be printed out for inspection.

IND provides a range of features and styles with convenience for the casual user as well as fine-tuning for the advanced user or for those interested in research. IND can be operated in a CART-like mode (but without regression trees, surrogate splits, or multivariate splits), and in a mode like that of the early version of C4. Advanced features enable more-extensive search, interactive control and display of growth of trees, and Bayesian and MML algorithms for pruning and smoothing of trees. These features often produce more-accurate class-probability estimates at the leaves. IND also includes a comprehensive experimental control suite.

IND consists of four basic kinds of routines: data-manipulation routines, tree-generation routines, tree-testing routines, and tree-display routines. The data-manipulation routines are used to partition a single large set of data into smaller training and test sets. The generation routines are used to build classifiers. The test routines are used to evaluate classifiers and to classify data by use of classifiers. The display routines are used to display classifiers in various formats.

IND is written in C language for Sun4-series computers. It consists of several programs with controlling shell scripts. Extensive UNIX man entries are included. IND is designed to be used on any UNIX system, although it has been tested thoroughly on Sun computers only. The standard distribution medium for IND is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. An electronic copy of the documentation in PostScript format is included on the distribution medium. IND was developed in 1992.

This program was written by Wray Buntine of **Ames Research Center**. *For further information,* ***write in 28*** *on the TSP Request Card. ARC-13188*

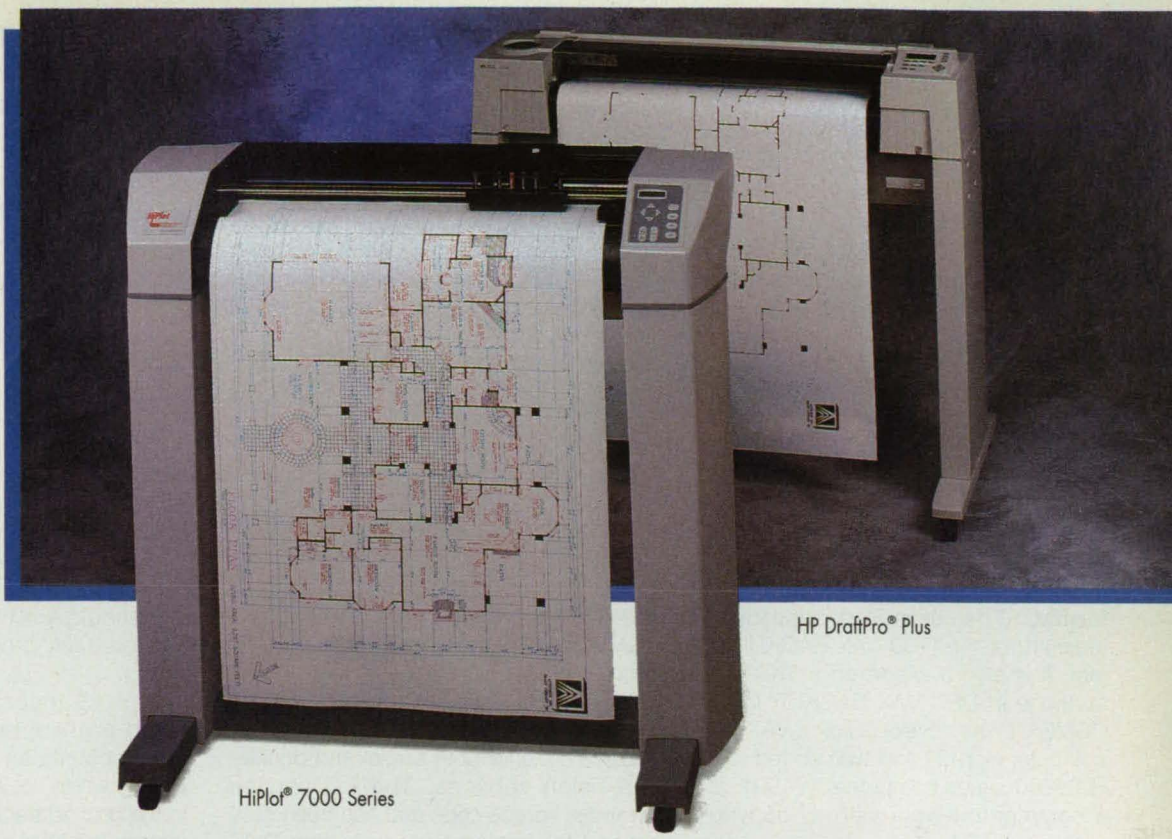
Mechanics

Conversion of Classical Orbital Elements

OSMEAN converts mean to osculating elements or vice versa.

OSMEAN is a sophisticated FORTRAN program that converts between osculating and mean classical orbital elements. Mean orbital elements are advantageous for designing trajectories and planning maneuvers because they can be propagated very quickly. However, mean elements cannot describe the exact orbit at any given time. Osculating elements enable an engineer to give an exact description of an orbit, but the cost of computational is significantly greater because of the numerical integration procedure required for propagation.

By calculating accurate conversions between osculating and mean orbital elements, OSMEAN enables the engineer to exploit the advantages of each approach for the design and planning or orbital trajectories and maneuvers. OSMEAN can convert mean elements to osculating elements or vice-versa. The conversion is based on mathematical modeling of all first-order aspherical terrestrial, lunar, and solar gravitational perturbations plus a second-order aspherical term based on the second-degree central-body



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zonal perturbation.

OSMEAN is written in FORTRAN 77 for HP 9000-series computers running HP-UX (NPO-18796) and DEC VAX-series computer running VMS (NPO-18741). The HP version requires 388K of random-access memory for execution, and the DEC VAX version requires 254K of random-access memory for execution. Sample input and output are listed in the documentation. Sample input is also provided on the distribution medium. The standard distribution medium for the HP 9000-series version is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. This version is also available on a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in IOTAMAT format or on a 3.5-in. (8.89-cm) diskette in UNIX tar format. The standard distribution medium for the DEC VAX BACKUP format. It is also available on a TK50 tape cartridge in DEC VAX BACKUP format. OSMEAN was developed on a VAX 6410 computer in 1989 and was ported to the HP 9000-series computers in 1991. It is a copyrighted work with all copyright vested in NASA.

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This program was written by Joseph R. Guinn, Ramachand S. Bhat, Mark A. Vincent, and Alexander S. Konopliv of Caltech for NASA's **Jet Propulsion Laboratory**. *For further information,* ***write in 39*** *on the TSP Request Card. NPO-18741/18796.*

Composite-Plate-Buckling Analysis Program

High-order displacement functions are used instead of traditional finite-element analysis.

The Composite-Plate-Buckling Analysis Program (COMPPAP) was written to help engineers determine buckling loads of orthotropic or isotropic irregularly shaped plates without need to perform manual calculations and without extensive finite-element mathematical modeling. COMPPAP is a one-element finite-element program that utilizes high-order displacement functions to perform a plane-stress analysis of a general plate followed by a buckling calculation based on the stresses found in the plane-stress solution. The high order of the displacement functions enables the user to obtain results more accurate than those obtained by use of traditional h-version finite elements. In the current version of COMPPAP, the plate is flat, of uniform thickness, and subject to a constant normal or shear load on one or more edges.

COMPPAP uses the power method to find the eigenvalues of the buckling problem. The power method provides an efficient solution when only one eigenvalue is desired. Once the eigenvalue is found, the eigenvector, which corresponds to the shape of the plate buckling mode, is obtained as a by-product. A positive feature of the power method is that the dominant eigenvalue is the first one found; in this case, the dominant eigenvalue is related to the lowest buckling load.

COMPPAP is written in ANSI FORTRAN 77. Two machine versions are available from COSMIC: a version (MSC-22428, this article) for computers of the IBM PC 386 and higher series and for compatible computers; and a UNIX version (MSC-22286). The distribution medium for both machine versions includes source code for both single- and double-precision versions. The PC version includes source code that has been optimized for implementation within DOS memory constraints as well as sample executable codes for both the single- and double-precision versions. The double-precision versions have been successfully implemented on an IBM PC 386- compatible computer running MS-DOS, a Sun4-series computer running SunOS, an HP-9000 series computer running HP-UX, and a CRAY X-MP computer running UNICOS.

COMPPAP requires 1MB of random-access memory and the BLAS and LINPACK math libraries, which are included on the distribution medium. The COMPPAP documentation provides instructions for using the commercial post-processing package PATRAN for graphical interpretation of COMPPAP output. The UNIX version includes two electronic versions of the documentation: one in LATEX format and one in PostScript format. The standard distribution medium for the PC version is a 5.25-in. (13.335-cm), 1.2MB MS-DOS-format diskette. The standard distribution medium for the UNIX version (MSC-22286) is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge (Sun QIC-24) in UNIX tar format. For the UNIX version, alternate distribution media and formats are available upon request. COMPPAP was developed in 1992.

This program was written by James P. Smith of **Johnson Space Center.**

For further information on MSC-22428, ***write in 203*** on the TSP Request Card.

For further information on MSC-22286, ***write in 204*** on the TSP Request Card. MSC-22428/MSC-22286

Computing Satellite Maneuvers for a Repeating Ground Track

Mathematical models account for all significant perturbations of the trajectory.

The TOPEX/POSEIDON Ground Track Maintenance Maneuver Targeting Program (GTARG) was developed to assist in designing maneuvers to maintain the orbit of the TOPEX/POSEIDON satellite. These maneuvers ensure that the ground track is kept within 1 km of a pattern that repeats exactly at intervals of approximately 9.9 days. Targeting strategies used by GTARG either maximize the time between maneuvers (longitude targeting) or force control band exit to occur at specified intervals (time targeting). A runout mode allows for ground-track propagation without targeting.

GTARG incorporates an analytic mean-element propagation algorithm that accounts for all perturbations that are known to cause significant variations in the ground track. These perturbations include the oblateness of the Earth, luni-solar gravitation, drag, thrusts associated with impulsive maneuvers, and unspecified fixed forces acting on the satellite in the direction along the trajectory.

The geopotential field is computed in GTARG by use of Merson's extension of Grove's theory. Kaula's disturbing function is used to include the luni-solar gravitational perturbations. GTARG includes a mathematical model of drag, unique to the satellite, that incorporates an approximate mean orbital Jacchia-Roberts atmosphere and a variable mean area model. Mathematical models of errors account for uncertainties in determination of orbits, errors in execution of maneuvers, unpredictability of drag, and use of the knowledge of fixed forces along the trajectory. Changes in velocity during maneuvers are targeted to maintain precisely either the unbiased ground track or a comfortable (three-standard-deviation) error envelope about the unbiased ground track.

GTARG is written in VAX-FORTRAN for DEC VAX computers running VMS. GTARG output is provided in two forms: an executive report summary in tabular form, and a plot file formatted as EZPLOT input namelists. Although the EZPLOT program and documentation are included with GTARG, EZPLOT requires PGPLOT, which was written by the Astronomy Department of the California Institute of Technology and is not available through COSMIC. GTARG users without access to PGPLOT may

therefore want to use a standard spreadsheet program to produce plots of the tabular ground-track data stored in the executive report summary. Alternatively, with the help of information found in the GTARG User's Reference Manual, the user can write a graphical interpreter program of his or her choice. The standard medium for distribution of GTARG is a 1,600-bit/in. (≈630-bit/cm), 9-track magnetic tape in DEC VAX BACKUP format. It is also available on a TK50 tape cartridge in DEC VAX BACKUP format. GTARG was developed in 1993 and is a copyrighted work with all copyright vested in NASA.

This program was written by Bruce Shapiro of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 233*** *on the TSP Request Card. NPO-19257*

Materials

Programs for Predicting Fatigue and Creep-Fatigue Resistances

Software characterizes behavior and predicts life of metallic materials in high-temperature,long-life regime.

TS-SRP/PACK is a set of computer programs for characterizing and predicting fatigue and creep-fatigue resistances of metallic materials under isothermal and nonisothermal fatigue conditions in the high-temperature, long-life regime. The programs implement the total-strain version of the strainrange-partitioning (TS-SRP) method.

The user should be thoroughly familiar with the TS-SRP method before attempting to use any of these programs. The document for this program includes a theory manual as well as a detailed user's manual with a tutorial part to guide the user in the proper use of TS-SRP.

An extensive data base has also been developed in a parallel effort. This data base is an excellent source of high-temperature, creep-fatigue test data and can be used with other life-prediction computer codes as well.

Five programs are included in TS-SRP/ PACK along with the alloy data base. The TABLE program is used to print the sets of data (which are supplied in NAMELIST format), in a format that is easier to read. INDATA is used to create new sets of data or add to existing ones. The FAIL program is used to characterize the failure behavior of an alloy as given by the constants in the strainrange-life relations used in the TS-SRP method and the inelastic-strainrange-based version of the SRP method. The program FLOW is used to characterize the flow behavior (the constitutive response) of an alloy as given by the constants in the flow equations used in the TS-SRP method. Finally, LIFE predicts the life of a specified cycle, using the constants that characterize failure and flow behavior determined by FAIL and FLOW. LIFE is written in interpretive BASIC to avoid compiling and linking every time the constants in the equations are changed.

Four out of five programs in this package are written in FORTRAN 77 for IBM PC-series and compatible computers running MS-DOS and are designed to read data by use of the NAMELIST format statement. The fifth is written in BASIC version 3.0 for IBM PC-series and compatible computers running MS-DOS version 3.10. The executable codes require at least 239K of memory and DOS 3.1 or higher. To compile the source code, a Lahey FORTRAN compiler is required. Modifications of the source will be necessary if the compiler to be used does not support NAMELIST input. Probably the easiest revision to make is to use a list-directed READ statement. The standard distribution medium for this program is a set of two 5.25-in. (13.34-cm) 360K MS-DOS-format diskettes. The contents of the diskettes are compressed by use of the PKWARE archiving software tools. The utility software to unarchive the files, PKUNZIP.EXE, is included. TS-SRP/ PACK was developed in 1992.

This program was written by J. F. Saltsman of **Lewis Research Center**. *For further information,* ***write in 97*** *on the TSP Request Card. LEW-15653*

Program for Analysis of Metal-Matrix Composites

METCAN simulates nonlinear behaviors of composites and their constituents.

High-temperature metal-matrix composites offer great potential for use in advanced aerospace structures. The realization of this potential, however, requires concurrent developments in (1) technology for fabrication of high-temperature metal-matrix composite structural components, (2) experimental

techniques for measuring their thermal and mechanical characteristics, and (3) computational methods to predict their behavior. METCAN (METal matrix Composite ANalyzer) is a computer program developed to predict this behavior. METCAN can be used to simulate computationally the nonlinear behavior of high-temperature metal-matrix composite structural components in specific applications, providing comprehensive analyses of thermal and mechanical performances.

METCAN treats nonlinearity of a composite material at the constituent (fiber, matrix, and interphase) level, where the behavior of each constituent is modeled, accounting for the dependences among time, temperature, and stresses. The properties of the composite are synthesized from the instantaneous properties of the constituents by making use of composite micromechanics and macromechanics. Factors that affect the behavior of the properties of the composite include the variables of the fabrication process, the properties of the fiber and matrix, the bonding between the fibers and matrix, and/or the properties of the interphase between the fiber and matrix.

A METCAN simulation is performed as a pointwise analysis and produces composite properties that are readily incorporated into a finite-element code to perform a global structural analysis. After one iteration of the global structural analysis has been performed, METCAN decomposes the properties of the composite back into the localized responses at the various levels of the simulation. Then the properties of the constituents are updated, and the next iteration in the analysis is initiated. This cyclic procedure is an instance of the integrated approach to analysis of metal-matrix composites.

METCAN-PC is written in FORTRAN 77 for IBM PC-series and compatible computers running MS-DOS. An 80286 machine with an 80287 math coprocessor is required for execution. The executable code requires at least 640K of random-access memory and DOS 3.1 or higher. The package includes sample executable codes that were compiled under Microsoft FORTRAN v. 5.1. The standard distribution medium for this program is one 5.25-in. (13.34-cm), 360K MS-DOS-format diskette. The contents of the diskette are compressed by use of the PKWARE archiving software tools. The utility software to unarchive the files, PKUNZIP.EXE, is included. METCAN-PC was developed in 1992.

This program was written by P. L. N. Murthy of **Lewis Research Center** *and S. K. Mital of the University of Toledo. For further information,* ***write in 75*** *on the TSP Request Card. LEW-15711*

Physical Sciences

Program Computes Dendrite-Settling Velocities

This program is based on empirical relationships among velocity, physical properties and shape.

The motion and gravitational settling of free floating crystals and grain fragments can cause macrosegregation and can influence the structure of metal castings. An understanding of how the highly nonspherical shape of a metal crystal influences its positioning characteristics is needed to predict the structure and segregation in castings. The empirical results of previous studies have been used to develop the DENDRIFT computer code, which calculates the settling velocities of metal-alloy crystals of various shapes. DENDRIFT also calculates a number of other parameters of interest such as the volume and surface area of a dendrite. The program requires, as input, the physical properties of the material system, and some geometric parameters of the dendrite under consideration, such as the average radius of the primary arm.

DENDRIFT exploits the concept of an envelope around the dendrite to enable the calculation of an effective sphericity. In comparison with results of an experimental study of model dendrites, the settling velocities predicted by the code were found to be, on average, within 5 percent of measured values. The predictions of the code were also found to be consistent and in good agreement with results of three other experimental investigations. Thus, incorporation into the code of the empirical relationships among velocity, sphericity, and envelope permeability appear valid, as do wall and inertial correction factors developed for this code. In its current form, DENDRIFT does not account for gradients in composition or density, interactions between particles, tertiary dendrite arms, or the possible influences of off-axis (tilted) dendrite settling.

This program can also be used to estimate the settling velocities of spheres and cylinders with hemispherical ends. The code can be useful as a subprogram in a comprehensive solidification/casting code. The concepts demonstrated in DENDRIFT may also be widely applicable in the chemical-processing industry by helping to describe the settling or floating of precipitates and flocs.

DENDRIFT is written in FORTRAN 77 for IBM PC-series and compatible computers running MS-DOS 3.0 or later and has been successfully implemented using Lahey v5.01-EM32. For execution, it requires 80K of random-access memory and an 80286, 80386, or 80486 processor. Sample input and output files and a sample DOS executable code are included with the distribution medium. The standard distribution medium for this program is one 5.25-in. (13.335-cm), 360K MS-DOS-format diskette. DENDRIFT was developed in l992.

This program was written by Henry de Groh, III, of **Lewis Research Center;** *Patrick Weidman and Riad Zakhem of the University of Colorado; and Christopher Beckerman and Sandeep Ahuja of the University of Iowa. For further information,* ***write in 225*** *on the TSP Request Card. LEW-15751*

Program Gives Data on Physical Properties of Hydrogen

TAB II provides values of thermodynamic and transport properties.

The TAB II computer program provides values of thermodynamic and transport properties of hydrogen in a useful format. In many problems, the properties have to be evaluated at numerous thermodynamic state points. TAB II provides these values for equilibrium hydrogen and para-hydrogen. The program is fast, moderately accurate, and operates over wide ranges of input variables.

For input, TAB II requires either one of two pairs of variables; (1) pressure and temperature or (2) pressure and enthalpy. The program covers (1) the pressure range from 1 to 5,000 psia (about 7 kPa to about 34 MPa) and the temperature range from the triple point to 6,000 R (about 3,300 K) or (2) enthalpies from about -130 Btu/lb (-623 J/mole) to about 25,000 Btu/lb (117,000 J/mole). Output variables include enthalpy or temperature, density, entropy, thermal conductivity, viscosity, speed of sound, heat capacity at constant pressure, heat capacity at constant volume, the ratio between the

heat capacity at constant pressure and the heat capacity at constant volume, and a heat-transfer parameter. Values of properties on the liquid and vapor boundaries are conveniently obtained through two small routines. TAB II achieves rapid output by use of linear interpolation in a grid of precomputed points that define the surface of values of the property to be interpolated. The maximum errors arising from the linear interpolation are shown on individual deviation plots for each combination of variables. Estimates of errors in the sources of data are similarly displayed.

TAB II is written in FORTRAN 77 for IBM PC-series and compatible computers running MS-DOS. A sample executable code is included. The standard distribution medium for this program is one 5.25-in. (13.335-cm), 360K MS-DOS-format diskette. The contents of the diskette are compressed by use of the PKWARE archiving software tools. The utility software to unarchive the files, PKUNZIP.EXE, is included. TAB II was originally developed in FORTRAN IV for use on IBM 360-series computers. This updated version was created in 1992, and includes some updated data as well as code that has been rewritten in FORTRAN 77.

This program was written by H. M. Roder, R. D. McCarty, and W. J. Hall of the National Institute of Standards and Technology for **Lewis Research Center.** *For further information,* ***write in 224*** *on the TSP Request Card. LEW-15626*

Electronic Systems

DET/MPS — The GSFC Energy Balance Programs

DET/MPS determines and computes energy balance for DET and MPS-type spacecraft power systems.

The Direct Energy Transfer (DET) and the MultiMission Spacecraft Modular Power System (MPS) computer programs perform mathematical modeling and simulation to aid in both the design and analysis of DET and MPS spacecraft power system performance in order to determine the energy balance of the subsystem. Typically, the DET spacecraft power system feeds the output of the solar photovoltaic array and the nickel cadmium batteries directly to the spacecraft bus. In a MPS system, the Standard Power Regulator Unit (SPRU) is utilized to operate the array at the array's peak power point. DET and MPS perform a minute-by-minute simulation of the performance of the power system as it responds to various orbital and operational parameters. The results of the simulation focus mainly on the output of the solar array and the characteristics of the batteries.

While both software packages are limited in terms of orbital mechanics, they have sufficient capability to calculate data on eclipses and performance of arrays for circular or near-circular orbits. DET and MPS can be adjusted to run one orbit or a sequence of orbits as long as 1 week in simulated time. These programs have been used on a wide variety of spacecraft projects in Goddard Space Flight Center.

DET and MPS are written in FORTRAN-77 with some VAX FORTRAN-type extensions. Any FORTRAN compiler that includes VAX extensions should be able to compile and run the programs with little or no modification. The compiler must at least support tab-delineated source format and "do do-while-end-do" control structures. DET and MPS are both available in three versions: GSC-13374, for DEC VAX-series computers running VMS, is available in DEC VAX BACKUP format on a 9-track, 1600-bit/in. (630-bit/cm) magnetic tape (standard distribution) or on a TK50 tape cartridge; GSC-13443, for UNIX-based computers, is available on a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format; and GSC-13444, for Apple Macintosh computers running A/UX with either the NKR FORTRAN for AbSoft MacFORTRAN II compilers, is available on a 3.5-in. (8.89-cm) 800K Macintosh format diskette. Source code and test data are supplied. The UNIX version of DET or MPS requires 90K of main memory for execution. DET and MPS were originally developed in 1990.

"A/UX" and "Macintosh" are registered trademarks of Apple Computer, Inc. "VMS," "DEC VAX," and "TK50" are trademarks of Digital Equipment Corp. "UNIX" is a registered trademark of AT&T Bell Laboratories.

These programs were written by J. M. Jagielski of **Goddard Space Flight Center.** *For further information on the DEC VAX version,* ***write in 76*** *on the TSP Request Card. GSC-13374*

For further information on the UNIX version, ***write in 77*** *on the TSP Request Card. GSC-13443*

For further information on the A/UX version, ***write in 78*** *on the TSP Request Card. GSC-13444*

Dual-Mode Adhesive Pad

This device can be switched between sticking and peeling modes of operation.

Lyndon B. Johnson Space Center, Houston, Texas

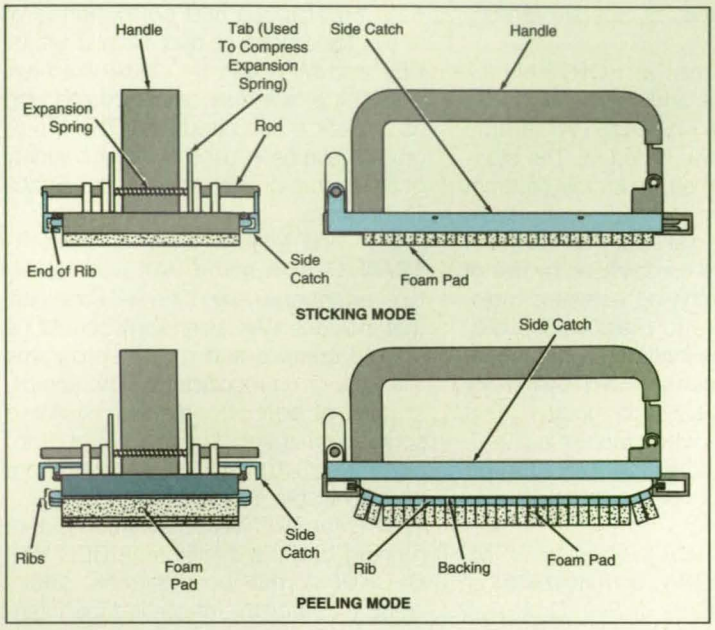
A tool helps a worker grip and move along a large, smooth structure that offers no handgrips or footholds. The tool adheres to a surface but can be easily released from it by actuating a simple mechanism. The original version of the tool was conceived for use as a movable anchor on the outer surface of a spacecraft. Modified versions could be useful in such diverse operations as inspecting hulls of ships and scaling walls in rescue operations.

The tool includes a handle and a segmented contact-adhesive pad (see figure). The bulk of the pad is made of soft plastic foam that conforms to the surface of the structure. Each segment of the pad is reinforced with a rib.

In the sticking mode, side catches engage the ends of the ribs, constraining all the ribs to lie in the same plane. Thus, the ribs stiffen the pad and distribute the load throughout the pad, which sticks firmly to the surface.

When the user compresses an expansion spring, the side catches release the ribs. This relaxes the pad, so that the load is concentrated in the two outermost sticking segments. With the adhesive force thus weakened, the pad can easily be peeled away from the surface.

The user sticks several such tools on the surface and proceeds to move across the surface, hand over hand, by grasping the handles of the tools. By releasing tools and reapplying them, the user can traverse the surface indefinitely. The user can also string a tether between tools and move along the tether.



In the Sticking Mode, ribs are braced by side catches. In the peeling mode, side catches are retracted, and the segmented adhesive pad loses its stiffness.

This work was done by Leslie Hartz of **Johnson Space Center**. *For further information,* ***write in 72*** *the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 20]. Refer to MSC-21955.

Computing Response of a Structure to Random Transient Pressures

A deterministic method yields more accurate prediction.

John F. Kennedy Space Center, Florida

An improved method of computing the vibrational response of a structure to transient random acoustic excitation at predominantly low frequencies has been devised. The method is called "deterministic" (1) to distinguish it from an older probabilistic method in which the acoustic excitation is approximated as stationary with spatial correlation of a theoretical white noise and (2) because it is based partly on the use, in the equations of motion of the structure, of deterministic excitations derived from measured pressure histories. The development of the deterministic method was motivated by the need to analyze more accurately the vibro/acoustic responses of structures at spacecraft-launching facilities and thereby determine whether there is need for reinforcement or redesign to withstand the launch environment. The deterministic method can also be used to study such phenomena as earthquake motions, ocean waves, aircraft pressure gusts, responses of bridges to winds, and the effects of jet-engine noise on aircraft structures.

The probabilistic method has been found to be overconservative from one perspective in that the use of a steady-state input excitation to approximate a transient excitation leads to prediction

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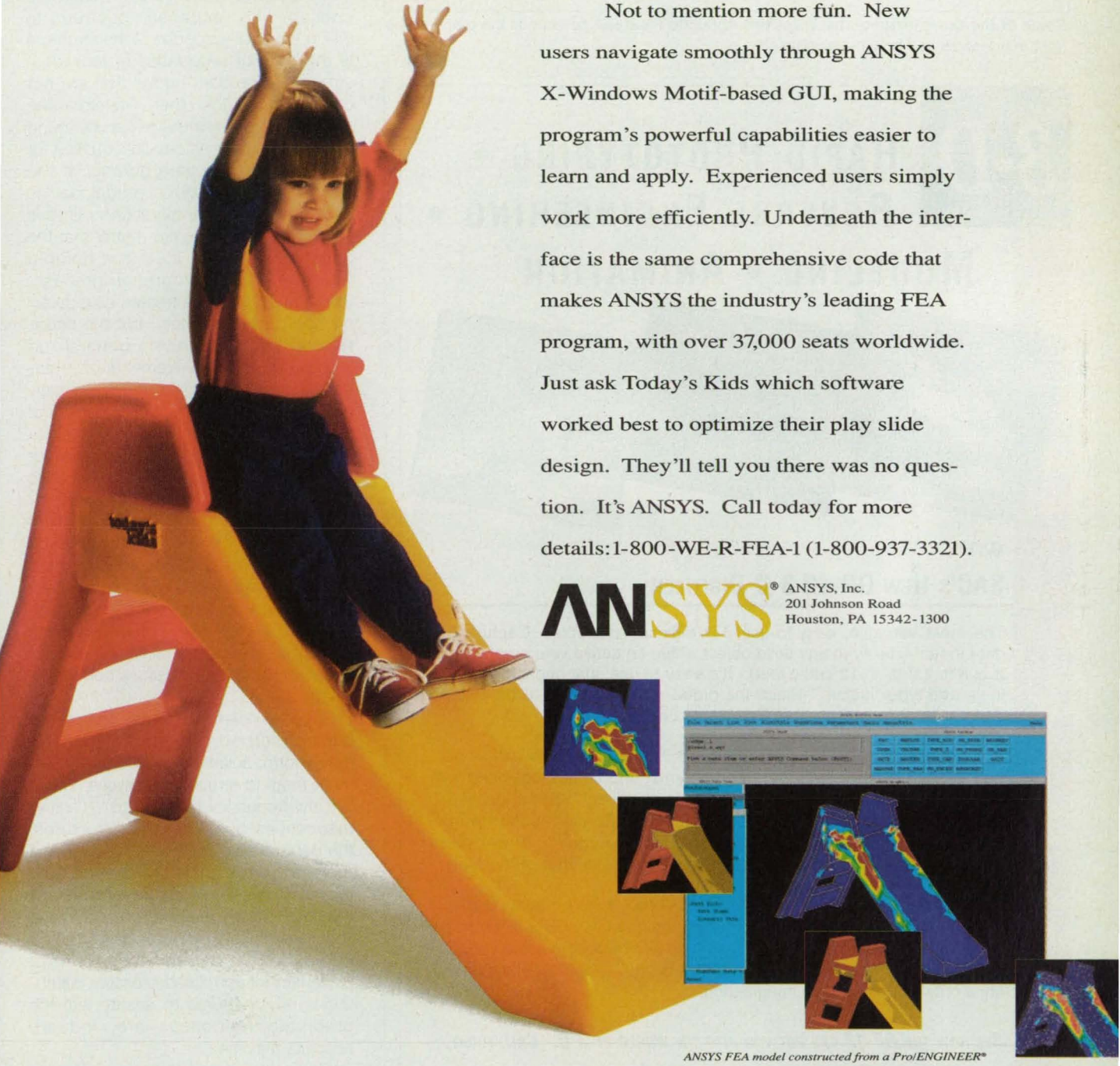
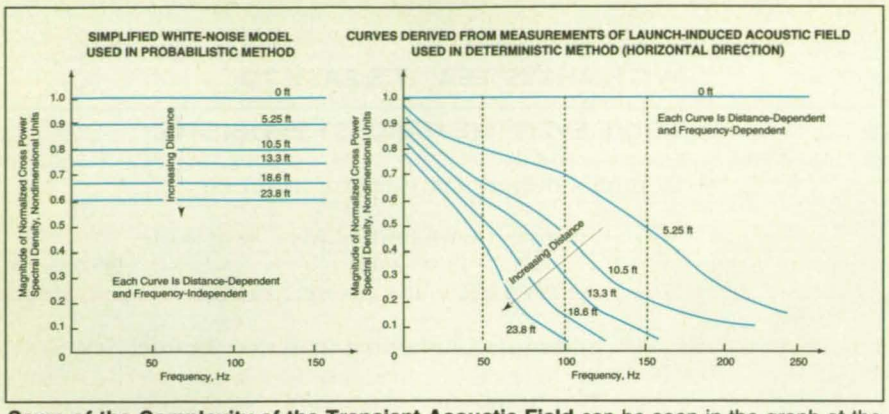


ANSYS FEA model constructed from a Pro/ENGINEER® assembly accurately showed that large, nonlinear deflections tripled the maximum stresses in the slide handrail.

Photograph and FEA model provided courtesy of Today's Kids, Dallas and DRD Corporation, Tulsa.

For More Information Write In No. 507



Some of the Complexity of the Transient Acoustic Field can be seen in the graph at the right, which is derived from measurements.

of unrealistically large vibrational stress and displacement responses and thus to overdesign and/or prediction of failures that do not occur. The probabilistic method is also potentially underconservative from another perspective in that it yields only root-mean-square values of response, whereas the peak values needed for design are based on assumed (unverified) distributions. The deterministic method focuses on peak values.

The deterministic method involves the concept of a response spectrum, in which the total response of the structure is the sum of responses in individual structural-vibration modes that are not coupled with each other. Therefore, the response in a given mode can be found by integrating the differential equation for that mode in the time domain. If the history of a generalized modal load is known, then such integration in time is possible, and it does not matter that the generalized modal load is a random transient. In the integration process, the input excitation is treated as a deterministic pressure history, but the definition of a corresponding generalized modal load contains elements of a random-response analysis and is uniquely related to the power spectral density of the generalized modal load.

A simple power spectral density alone is not sufficient to describe the acoustic field. To cope with the spatial and temporal complexity of the launch transient acoustic field, the deterministic method includes additional related spectral measures: the normalized cross power spectral density (see figure), the correlated-pressure distribution (which provides a graphic illustration of vibro/acoustic coupling), and the pressure-correlation length.

Both the deterministic and the probabilistic method provide solutions in matrix form, suitable for use in finite-element-method structural analyses. Within the low-frequency range (0 to 20 Hz) of resonances of launch-pad structures, the deterministic method is simpler and more accurate than the probabilistic method is. One disadvantage of the deterministic method is that the correct prediction of peak generalized modal loads depends on correct placement of correlated pressure distributions on structures to ensure that the predicted responses are, indeed, absolute maxima.

This work was done by Valentin Sepcenko and Ravi Margasahayam of I-NET, Inc., for **Kennedy Space Center.** *For further information,* ***write in 36*** *on the TSP Request Card. KSC-11649*

M A T H C A D

Could this be the end of 7th row center?

To locate the best seat in the house, two heads are better than one.

For Dick Campbell, world-class acoustics engineer, electrical engineering professor and ardent concert-goer with an "excellent ear" for music, where he sits in a concert hall can be as important as the program he sits through.

"Not seventh row center. It's too close to the source. If you care more about watching the musicians than hearing the music, it's fine. But the best seats start a quarter of the way back from the stage." And that's not just Dick's personal taste. It's a fact based on the unimpeachable impartiality of observations made by Fred (he's the one on the left, Dick's the one with a tie).

Dick, a member of the Concert Hall Research Group, employs dummies like Fred to map the acoustics of concert halls around the world, including Symphony Hall in Boston and Washington's Kennedy Center.

First, the dummy occupies various seats throughout the hall, each time listening to test sounds digitally recorded through microphones installed in its head. Then, the data is read into Mathcad® PLUS 5.0 for interaural cross correlation analysis using the Signal Processing Function Pack. This involves octave filtering of the left and right impulse reponses and picking out the maximum cross correlation of the octave-filtered pairs. It's a mildly controversial technique used for mathematical modeling of something otherwise ordained by still-quibbling critics, specifically, what makes a concert hall sound good.

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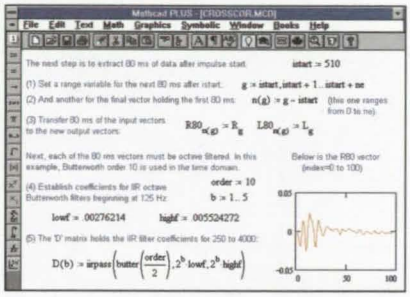
Interaural cross correlation analysis using Mathcad PLUS 5.0.



But the importance of this work is not debated among his students. They study Dick's documents directly in Mathcad, revealing principles of acoustics in a way Dick calls "very much alive. They can manipulate the equations and graphs right there in front of them. They can visualize what's going on, not just do math all day long. It lets them look at a problem like it's under a magnifying glass."

Mathcad also lets Dick explore in a way that "might not be attempted otherwise." Like using a 20-term series expansion to find the first seven combined resonance frequencies for a coupled driver and standing wave tube. "You wouldn't even try this with a calculator. And the human factor of Mathcad makes it much faster than programming."

Which leaves but one probing question unanswered. Are there any bargain seats in the great halls of the world? "No, not really. But don't ever sit under the balcony. That's the worst."

Dick Campbell, EE, Professor, Worcester Polytechnic Institute, Worcester, MA.

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M A T H C A D

What makes calculating just like home remodeling?

For Denzil Hellesen, it's the fact that neither one ever seems to end.

When mechanical engineer Denzil Hellesen takes on a project, you can bet it's going to be big. Big, like the design of a 10,000 PSI autoclave, up to 18 feet in diameter. Big, like the single Mathcad file (nearly a pound when printed) used to solve and document every calculation in the autoclave's spec. Or if you want to talk really big, let's talk about Denzil remodeling his home.

By day, Denzil is a fierce and fearless number cruncher, building colossal programs in Mathcad, uniting hundreds of related calculations into single, seamless documents. "Typically, they run 75 to 100 pages," says Denzil, including all the live math, graphs and documentation. Already, he boasts 50 megabytes of such Mathcad documents, all devoted to calculations he used to do by hand. Like the standard flange design that required 1500 steps on a calculator and consumed half a day (not counting mistakes). The same calculation set takes five minutes in Mathcad (and there are no mistakes).

Denzil will tell you it's not the math that's extraordinary ("mostly algebra and low level calculus"), but the way Mathcad lets him "go ahead and quickly produce results that people will understand. They stumble through calculations done with a computer language. But with Mathcad, they can actually see the math as you would write it."

And that's just by day. At night, Mathcad fires up again, this time in aid of Denzil's continuing adventure remodeling his home. "It's a never-ending process. I've done kitchen cabinets, bathrooms, you name it. Mathcad calculates how much material is required for each project." At which point he jokingly concedes that among the 50 megabytes of Mathcad programs he's written, "okay, a meg or two are for remodeling."

Denzil Hellesen, VP, ENMECO, Lebanon, MO

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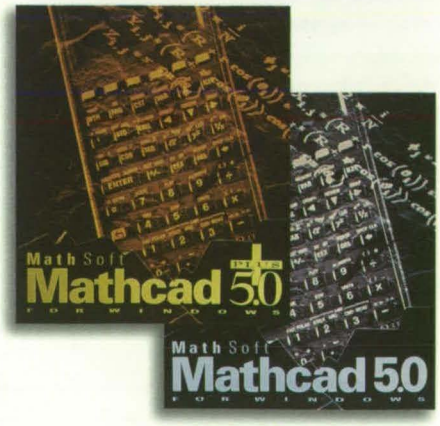

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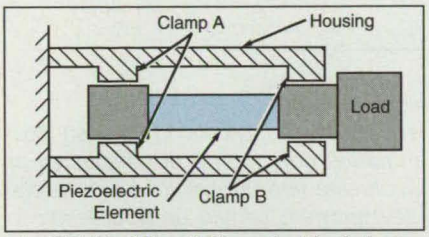
"Mighty Worm" Piezoelectric Actuator

The piezoelectric element would be removed from the load path when not in use.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure illustrates schematically a piezoelectric actuator that was under construction when the information was submitted for this article. This actuator is designed to operate in three modes:

1. as an adjustable static structural member, the length of which can be changed slowly in a sequence of wormlike increments of motion;
2. as an active vibrator or vibration suppressor when operated in conjunction with a vibration sensor and a feedback control system; or
3. as a simple inactive structural element.



The **"Mighty Worm" Piezoelectric Actuator** can be used as an adjustable-length structural member, an active vibrator or vibration suppressor, and acts as a simple (fixed-length) structural member when inactive. The load force is not applied to the piezoelectric element in the simple-structural-member mode.

The device is called a "mighty worm" actuator because in mode 3 it can withstand a greater axial load force than can older piezoelectric devices called "inchworm" actuators.

This actuator includes two subassemblies that move relative to each other. One subassembly includes a housing and clamps. The other subassembly includes the piezoelectric element (a stack of piezoelectric disks), clamping surfaces at the ends of the piezoelectric element, and a load (the lengthwise position of which is to be adjusted). Each clamp comprises a pair of cam-actuated spring-and-lever mechanisms, and the cams can be driven by a rotary actuator to apply or release clamping force as commanded.

The sequence of functions in the length-adjustment mode (mode 1) to move the load to the right is the following:

1. Clamp A, unclamp B, then energize the piezoelectric element.
2. Clamp B, unclamp A, then deenergize the piezoelectric element.
3. Repeat steps 1 and 2, as necesary, until the load has moved to the desired position.

The sequence to move the load to the left is similar except that A and B are interchanged.

In the vibration-control mode (mode 2), A is clamped, B is unclamped, and the piezoelectric element is energized by the feedback control system. In the simple-structural-member mode (mode 3), A is unclamped, B is clamped, and the piezoelectric element is deenergized: the actuator can withstand a relatively high axial force in this mode because the piezoelectric element is removed from the load path.

This work was done by Robert M. Bamford, Ben K. Wada, and Donald M. Moore of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 15*** *on the TSP Request Card. NPO-19046*

Turbine-Driven Pipe-Cleaning Brush

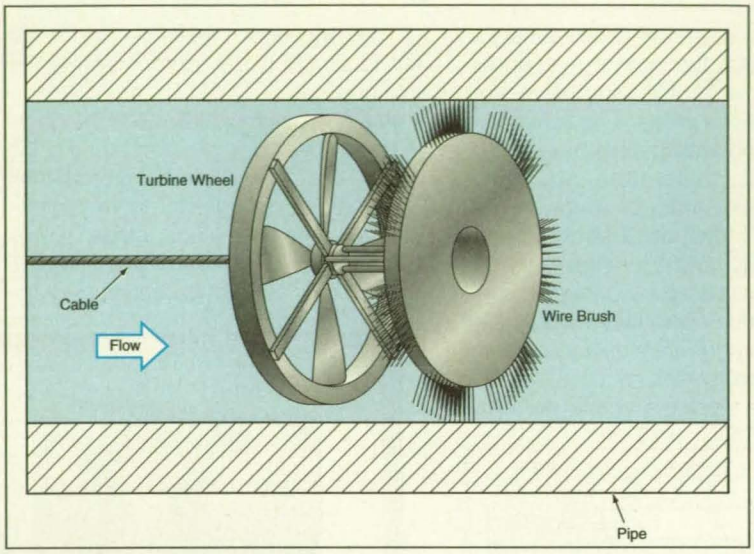
The flow of cleaning solution turns the turbine.

John F. Kennedy Space Center, Florida

A simple pipe-cleaning device includes a small turbine wheel axially connected, by a standoff, to a circular brush (see figure). The turbine wheel turns on a hub bearing attached to the end of an upstream cable. The turbine-and-brush assembly is inserted in a pipe with the cable trailing upstream and the brush facing downstream.

The water or cleaning solution is then pumped through the pipe. The cable is held at its upstream end, so that it holds the turbine and brush in the pipe at the location to be cleaned. The flow in the pipe turns the turbine, which turns the wheel, producing the desired cleaning action. In addition to brushing action, the device provides even mixing of cleaning solution in the pipe.

Of course, the turbine and brush must be sized to fit the inner diameter of the pipe to be cleaned, and the wire must be sufficiently long to enable the turbine-and-brush assembly to reach and traverse the part to be cleaned. The turbine-and-brush assembly can traverse long pipes and it can travel around 90° bends and through pipe fittings.



The **Turbine Wheel Turns** in the flow in the pipe, rotating the wire brush to clean the inside of the pipe. The cable holds the turbine-and-brush assembly against the flow.

This work was done by Rudy J Werlink and David E. Rowell of **Kennedy Space Center.** *For further information,* ***write in 270*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Kennedy Space Center [see page 20]. Refer to KSC-11669.

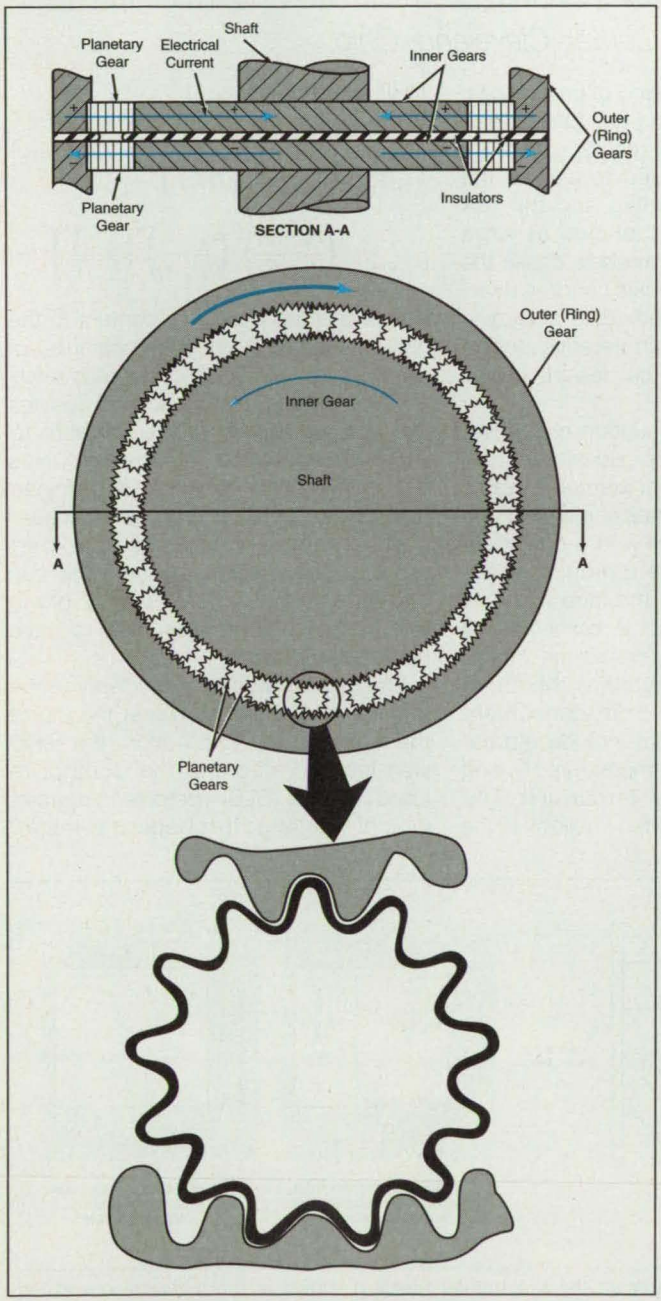
Geared Electromechanical Rotary Joint

Springy planetary gears provide low-noise electrical contact.

Goddard Space Flight Center, Greenbelt, Maryland

The figure illustrates a geared rotary joint that provides low-noise ac or dc electrical contact between electrical subsystems that rotate relative to each other. This joint is designed to overcome some of the disadvantages of older electromechanical interfaces — especially the intermittency (and, consequently, the electrical noise) of sliding-contact and rolling-contact electromechanical joints.

The first electrical subsystem is mounted on, or at least rotates with, the shaft and the two inner gears attached to the shaft. The inner gears are separated axially by an electrically insulating disk. Each inner gear constitutes one of two electrical terminals through which electrical power is fed to or from the first electrical subsystem.



Hollow, Springy Planetary Gears provide continuous, redundant, low-noise electrical contact between the inner and outer gears.

The second electrical subsystem is mounted on, or at least rotates with, the outer (ring) gears. Similarly to the inner gears, the ring gears are separated axially by an electrically insulating annular disk, and they constitute the electrical terminals through which power is fed from or to the second electrical subsystem.

Electrical contact between the inner and outer (ring) gears is provided by multiple, equally spaced, flexible planetary gears formed as hollow cylinders with thin, fluted walls. These gears mesh with the inner and outer (ring) gears. These gears are slightly oversize with respect to the gaps between the inner and outer gears, but their flexibility makes it possible to compress them slightly to install them in the gaps. After installation, meshing of the gears maintains the even angular interval between the planetary gears at all rotational speeds.

The planetary gears are made of beryllium copper, which is preferred for electrical contacts because it is a self-cleaning material that exhibits excellent current-carrying characteristics. A typical flexible planetary gear has 13 teeth, an axial length and an average diameter both ª0.25 in. (6.35 mm), and a wall thickness of 0.004 in. (0.10 mm). Because each planetary gear is independently sprung into a cylinder-in-socket configuration with respect to the inner and outer gears, it maintains continuous electrical contact between them. The reliability and continuity of the electrical contact is further ensured by the redundancy of the multiple planetary gears. The multiplicity of the contacts also ensures low electrical resistance and large current-carrying capacity.

The springiness of the planetary gears automatically compensates for thermal expansion, thermal contraction, and wear; moreover, wear is expected to be minimal. Finally, the springiness of the planetary gears provides an antibacklash capability in a gear system that is simpler and more compact in comparison with conventional antibacklash gear systems.

This work was done by John M. Vranish of **Goddard Space Flight Center.** *For further information,* ***write in 31*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20]. Refer to GSC–13540.

Simulation of Probabilistic Wind Loads on a Building

Results can be used to analyze tendencies toward sway, buckling, and/or overturning.

Lewis Research Center, Cleveland, Ohio

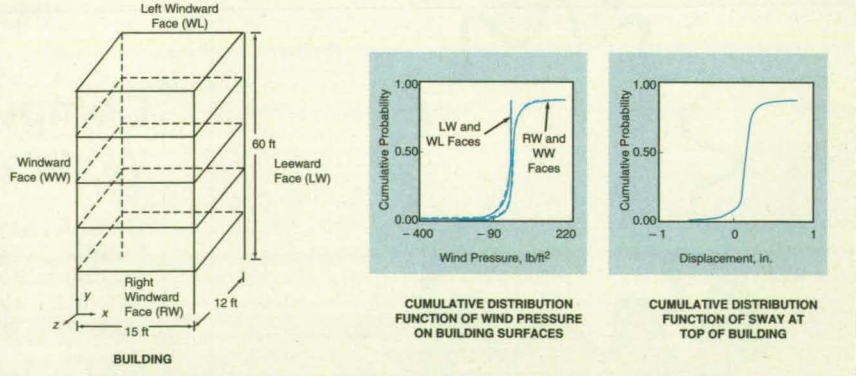
A method of simulating of probabilistic windloads on a building has been developed. The numerical results of such a simulation can be used to assess the reliability of the building and the risk associated with tendencies of large gusts or high steady winds to cause the building to sway, buckle, and/or overturn. Using of this method to analyze a proposed design in an iterative design cycle, a building can be designed for a specified reliability.

Wind pressure or suction on an upstream, downstream, or sidestream face of the building is approximated in this method by a mathematical model of the form $P_w = kS^2$, where k is a coefficient that depends on the direction of the wind with respect to the face and S is the speed of the wind. A semiempirical mathematical model, called the "multifactor interactive equation" (MFIE), is used to compute S from constituent primitive variables that include atmospheric pressure *(P)*, temperature *(T)*, and roughness height of terrain *(R)*. The effect of gusts is included implicitly in the MFIE, which is

$$\frac{S}{S_0} = \left(\frac{P_f - P}{P_f - P}\right)^a \left(\frac{T_f - T}{T_f - T}\right)^b \left(\frac{R_f - R}{R_f - R_0}\right)^c \left(\frac{\omega_f - \omega}{\omega_f - \omega_f}\right)^d \left(\frac{t_f - t}{t_f - t_0}\right)^e$$

where ω is the frequency content of the gust, t is the time since the beginning of the gust, the subscript 0 denotes reference conditions, the subscript f denotes the final condition of the variable to which it is appended, and the exponents a through e can either be determined through regression analysis of measured values or estimated by expert opinion. The variables in the MFIE can be random with any distribution, but in this method, all are assumed to have normal distributions.

The method was applied initially to the rectangular building shown at the top of the figure. In this application, the MFIE was incorporated into the Composite Load Spectra (CLS) computer program, which simulates probabilistic loads,



Probabilistic Windloads on the rectangular building shown at the left were computed. Some of the numerical results are plotted.

given the primitive variables, their statistical distributions, and the discrete probability intervals (histogram bins) required to discretize the input probability density functions. Then by use of Numerical Evaluation of Stochastic Structure Under Stress (NESSUS), which is a stochastic finite-element computer code, the simulated probabilistic wind loads were applied to the building to obtain cumulative distribution functions of sway displacements and reliability against overturning. Uncertainties in windloads and stochastic deviations of dimensions and properties of components of the building from nominal values were incorporated into NESSUS. Sensitivities of responses to changes in structural parameters were also computed. In the particular case, the sway was found to be sensitive to the wind pressure, height of the building, and properties of the building materials.

This work was done by Christos C. Chamis of **Lewis Research Center** *and Ashwin R. Shah of Sverdrup Technology, Inc. For further information,* ***write in 73*** *on the TSP Request Card.*
LEW-15685

Using a Digital *X-Y* Plotter as a Calibration Fixture

Repetitive measurements that involve precise positioning can be automated fairly easily.

Langley Research Center, Hampton, Virginia

A digital *x-y* plotter can be used as a programmable calibration fixture to make two-dimensional maps of the flux densities of small magnets. It could also be useful in other calibration procedures in which there is need for accurate two-axis positioning of small parts.

Accurate two-dimensional positioning of measurement devices is necessary for precise calibration. In the original application for which the use of a digital *x-y* plotter was conceived, there was a need for calibration of the flux densities of more than 100 small cylindrical permanent magnets. Inasmuch as the flux density of such a magnet is axisymmetric, it was necessary to map the flux densities in two dimensions only. However, the large number of magnets made it desirable to automate the measurement procedure.

One approach to the solution of the automated-measurement problem could have involved mounting two programmable linear translation stages together at right angles to form a calibration fixture. This approach would have necessitated considerable hardware, long setup time, and extensive programming on a desktop computer.

The use of a modified digital *x-y* plotter offered a much simpler solution. The probe of a gaussmeter was mounted at a fixed position to measure the flux density from the magnet under test. The magnet was attached to the pen holder of the plotter in the *x-y* plane of the plotter. Thus, by use of position commands of the type normally sent to the plotter from a personal computer, it was possible to position the magnet in *x* and *y*. A positioning resolution of ±0.001 in. (about ±0.03 mm) was achieved along both axes. This approach was easier, with respect to both implementation in hardware and programming the computer, than the other approach would have been.

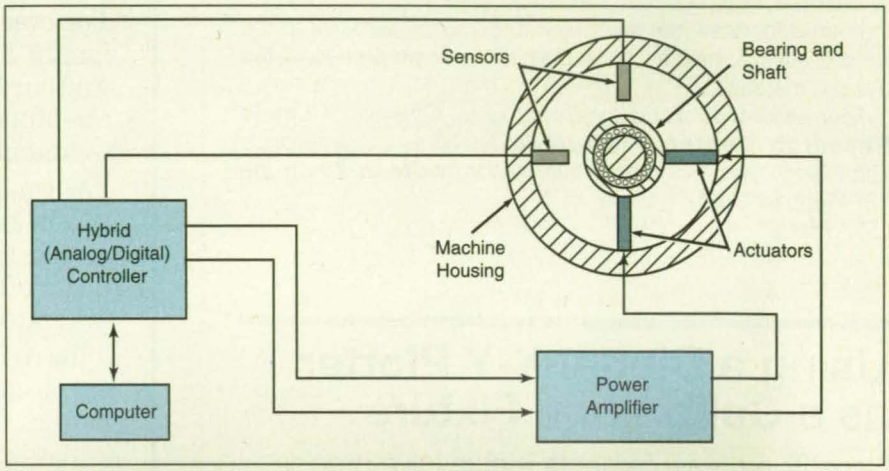
This work was done by Tom D. Finley of **Langley Research Center.** *No further documentation is available.*
LAR-14666

Dual-Actuator Active Vibration-Control System

Feedback gains and filter parameters can be adjusted according to schedules.

Lewis Research Center, Cleveland, Ohio

The dual-actuator active vibration-control (DAAVC) system is a developmental system of the type described in the "Active Vibration Dampers for Rotating Machinery" (LEW-15427), NASA Tech Briefs, Vol. 18, No.10 (October 1994), page 93. This system features sensors and actuators positioned and oriented at bearings to measure and counteract vibrations of a shaft along either of the two axes perpendicular to the axis of rotation. This system has been proven effective in damping vibrations of a helicopter-engine test stand, thereby making it safer to operate the engine at speeds near and above the first resonance of the engine/test-stand system. In so doing, the DAAVC system opens new opportunities for engine designers to draw more power from this engine, and the concept should be applicable to other rotating machines as well.



The **Dual-Actuator Active Vibration-Control System** is one in a continuing series of feedback control systems that are being developed to suppress vibrations in rotating machinery.

The DAAVC system (see figure) includes a hybrid analog/digital controller. Analog amplifiers and filters are used in the controller because they operate significantly faster than competing digital circuits do. The amplifier gains and filter settings are adjustable; maximum versatility is achieved by providing for downloading the gains and filter settings from a microprocessor or desktop computer via a digital-to-analog converter. The system is so capable that it even compensates for realistic misalignments of sensors and actuators.

The gain and filter adjustments can be easily scheduled as in response to (that is, as functions of) dc input signals that represent speed, torque, or other operating parameters. The computer can be made to execute a grid-search algorithm to select feedback gains that minimize a vibration norm (a composite measure of absolute values of vibration amplitudes). These gains are then downloaded as active stiffnesses and rates of damping with a linear fit throughout the range of operating speeds.

This work was done by Albert F. Kascak and Louis J. Kiraly of **Lewis Research Center**, *Gerald T. Montague of Sverdrup Technology, Inc., and Alan B. Palazzolo and Daniel Manchala of Texas A&M University. For further information,* ***write in 8*** *on the TSP Request Card.*

LEW-15765

Optimized Resolved-Rate Control of Telerobotic Manipulator

In a simulation, this technique caused a robot hand to move as commanded in real time.

Langley Research Center, Hampton, Virginia

Velocity control is a popular way to control robot arms. The velocity of a robot hand is known, or commanded by an operator, and this velocity is resolved into rates of change of joint angles (resolved-rate control) to move the hand as commanded. Six independent joints are all that are needed for general movement of the hand in its workspace, but the Laboratory Telerobotic Manipulator (LTM) has a seventh joint, providing more choices for pint-angle rates to move the hand.

The LTM (see figure) is a seven-degree-of-freedom robot arm built by the Oak Ridge National Laboratory for NASA for evaluation in ground-based research to assess the role of redundant-degree-of-freedom arms in outer-space operations. Each arm has three pitch/yaw joints: one at the shoulder, another at the elbow, and a third at the wrist. The seventh degree of freedom is provided by a wrist-roll joint.

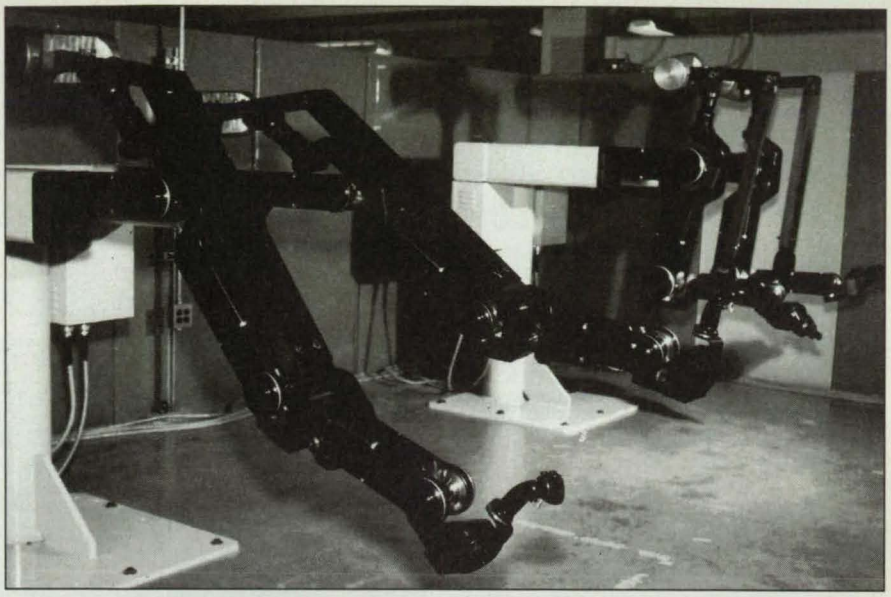
The movement of the elbow plays an indispensable role in the use of a human hand; for example, in working on a car. Sometimes the position of the elbow must be changed to gain access for the hand or to provide leverage for wrenching. The extra joint in the LTM provides this type of flexibility. Of course, the extra joint complicates the control problem, making it more difficult to generate commands to move the hand in real time; i.e., there is an increased computational burden.

Optimized resolved-rate equations were developed for real-time control of the LTM, along with special resolved-rate equations to handle kinematic singularities. These equations generate a least-squares solution for joint-angle rates, which are used to command the hand to move at a specified velocity. Optionally, the equations also represent a striving to configure the arm to satisfy a specified performance criterion with respect to the joint angles.

The equations have been programmed with application to a three-

dimensional-graphics simulation. The graphical model of the LTM is driven by velocity commands from a six-axis hand controller to assess the equations thus developed. An operator deflects a six-axis hand controller to essentially "fly" the robot hand; the operator tells the hand to move in a desired direction by commanding a velocity in that direction. The commanded velocity is resolved into the motions of the individual joints in the robot arm to move the hand. For the motions simulated thus far, the robot hand moves as commanded, and the special resolved-rate equations for kinematic singularities appear reasonable.

As redundant manipulators come into wider use, computationally efficient algorithms for inverse kinematics will become increasingly important. The approach tested on the LTM is practical for a class of manipulators. Because they offer the advantages of more efficient use of workspaces and the ability to reach around obstacles, redundant manipulators are expected to be used in mobile robots and teleoperators for hazardous environments, automotive assembly, welding, and spray painting. Practical resolved-motion control will be required in the implementation of such manipulators.



The **Laboratory Telerobotic Manipulator** of the Oak Ridge National Laboratory is shown here with counterbalancings. Each arm has three pitch-and-yaw joints and a wrist-roll joint.

This work was done by L. Keith Barker and William S. McKinney, Jr., of **Langley Research Center.** *Further information may be found in NASA TP-2938 [N90-10618/TB], "Optimized Resolved Rate Control of Seven-Degree-of-Freedom Laboratory Telerobotic Manipulator (LTM) with Application to 3-D Graphics Simulation."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, User Services Division, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number. LAR-14261

Rugged Preheaters for Vacuum Plasma Spraying

Units preheat large parts effectively.

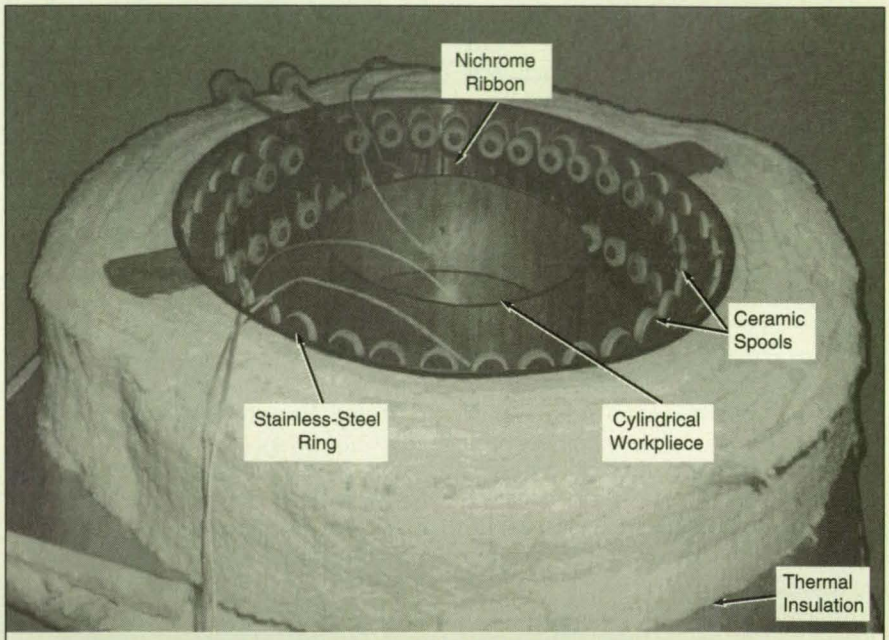
Marshall Space Flight Center, Alabama

Electric preheater units have been built to ensure that large workpieces to be coated with metals by vacuum plasma spraying are heated uniformly to the requisite high temperatures by the time the plasma torch arrives. For small workpieces, heating by quartz lamps or by the plasma torch itself suffices to ensure the proper temperatures. However, for large workpieces, a more dependable source of heat is needed.

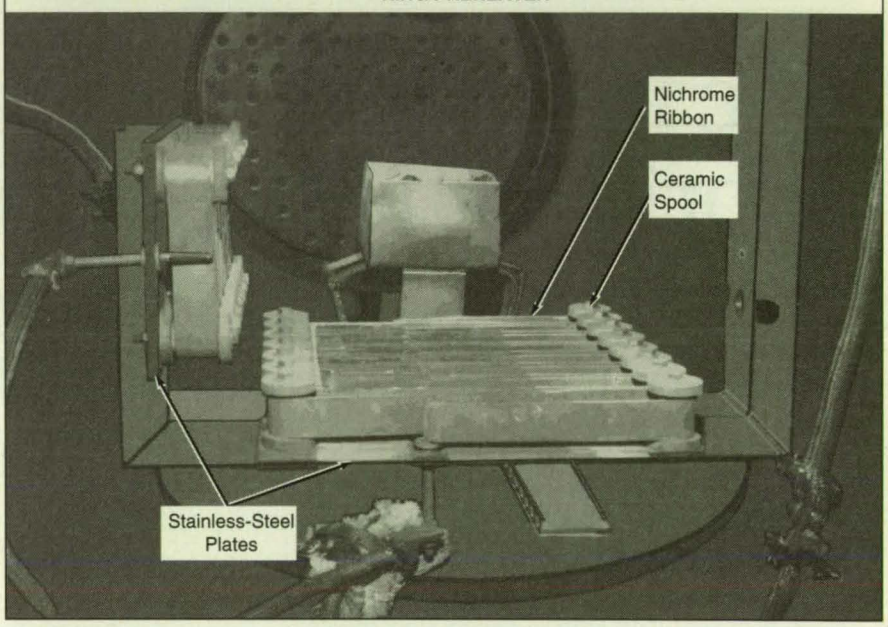
Typically, a workpiece to be vacuum-plasma-sprayed should be at a temperature between 800 and 2,000°F (430 and 1,100°C). On a large workpiece, the torch passes any given spot too infrequently to maintain the needed constant high temperature. As a result, there can be large temperature gradients in the workpiece, and the quality of the coating is adversely affected. Quartz lamps are often used to maintain the proper temperatures, but they do not last long in the hot, low-pressure, metal-powder-laden environment.

The present electric preheater units are similar to (but much larger than) the electrical-resistance ribbon heaters in toasters and in some small portable electric "space" heaters. Each unit includes an 80/ 20 nickel/chromium resistance heater ribbon 1.5 in. (3.81 cm) wide by 0.1 in. (0.254 cm) thick, supported and electrically insulated by ceramic spools (see figure). Each heater is designed to use power from a high-current (600-A), low-voltage power supply, the low voltage being advantageous in that it minimizes arcing in the process vacuum. These heater units outgas hardly at all and are relatively unaffected by the buildup of metal powder from the process. Each unit is connected to the power supply by a thick, thermally and electrically insulated wire via vacuum feedthroughs.

The ring preheater shown in the figure was used to heat cylindrical stainless-steel barrels 12 in. (about 30.5 cm) in diameter in a 40-torr (5.3-kPa) vacuum to a required temperature of 1,650°F (about 900°C). For this purpose, it was necessary to supply the heater with a current of 350 A at a potential of 53 V. The panel preheater shown in the figure was supplied at 180 A, 25 V to heat a valve housing to 815°F (435°C), also in a 40-torr vacuum. Thereafter, the power was decreased to 130 A at 18 V to maintain a temperature of 925°F (496°C) during plasma spraying. Both the ring and the panel preheaters have proved durable.



RING PREHEATER



Nichrome Resistance-Heating Ribbons are wrapped around ceramic insulating spools on rings and on plates. A round workpiece is placed in the middle of the ring preheater. Plate preheaters can be stacked as needed near a workpiece.

This work was done by William H. Woodford, Timothy N. McKechnie, Lewis D. Sander, Christopher A. Power, Heather L. Sander, and Dalton D. Nguyen of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 95*** *on the TSP Request Card. MFS-29983*

Shear-Wave Ultrasonic Inspection With a Dry Couplant

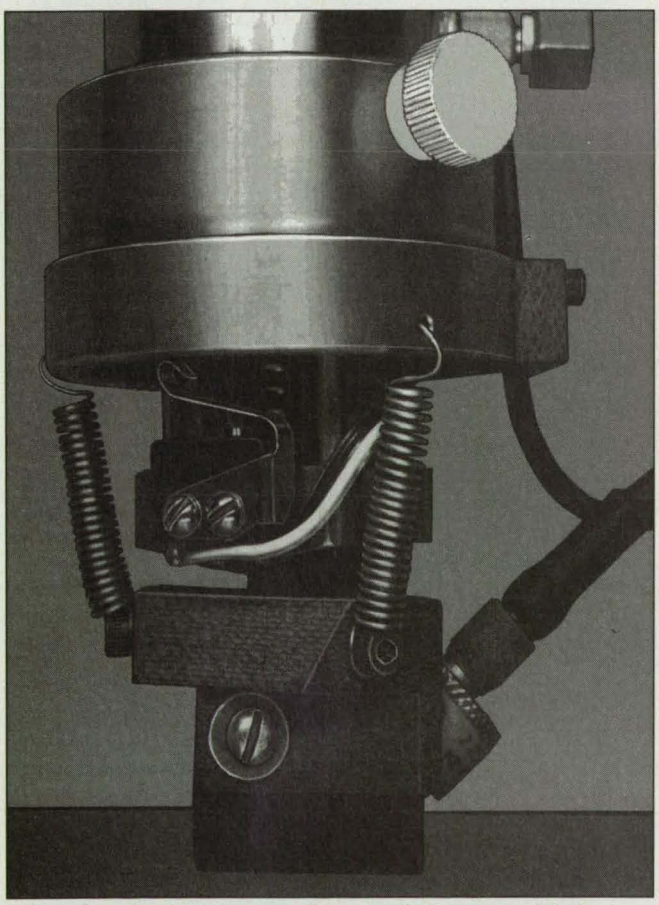
Liquid and gel couplants, which can contaminate workpieces, are not needed.

Marshall Space Flight Center, Alabama

An automated ultrasonic inspection system includes a dry couplant pad attached to an ultrasonic transducer, so that there is no need for a liquid or gel to couple ultrasonic shear waves between the transducer and the workpiece under test. Heretofore, it has been common practice to use a liquid or gel to transfer acoustic energy efficiently between an ultrasonic transducer and the workpiece. However, a liquid or gel couplant must eventually be cleaned off a workpiece and is thus undesirable in a manufacturing environment.

The present shear-wave ultrasonic inspection system with dry couplant is designed to be mounted on a robot arm in an automated manufacturing (robotic welding) work cell. Between, during, or after manufacturing operations, the robot can simply scan the ultrasonic transducer along the workpiece. The workpiece can be reworked in place, if necessary; there is no need to remove the workpiece from the work cell for testing and return it for further operations. In principle, the computer program that controls inspection can be overlaid on the computer program that controls the welding operations.

The dry couplant pad is made of a compliant encapsulated



A **Dry Couplant Pad** made of a compliant encapsulated epoxy material is attached to an ultrasonic-transducer wedge on the end of a robot arm. The robot arm presses the pad against a workpiece for ultrasonic-shear-wave inspection.

epoxy material and is attached as a facing to an ultrasonic-transducer wedge (see figure). The transducer wedge and couplant pad are pressed against the workpiece; the surface of the compliant pad conforms to the surface of the workpiece, ensuring transfer of acoustic energy with an efficiency lower than that of a liquid or gel couplant but nevertheless sufficient for the purpose. The contact surface of the pad can be made flat or curved to conform closely to the surface of the workpiece. The robot arm scans the transducer along the workpiece by alternately translating the transducer in small increments of position, then firmly seating the transducer and couplant pad on the workpiece at each position to apply approximately uniform contact pressure at the interface between the couplant pad and the workpiece.

In an experiment, a couplant pad was tested for 10,000 inspection cycles without a detectable change in its characteristics. For a 0.375-in. (9.5-mm) transducer with 0.125-in. (3.2-mm) overlap, this corresponds to a minimum life expectancy of 2,500 in. (63.5 m) of distance along a weld seam or other linear workpiece feature.

This work was done by James D. Willenberg and Lisa Van Wyk of Rockwell International Corp. for **Marshall Space Flight** *Center. For further information,* ***write in 61*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-29953.

Making Ceramic Reference Specimens Containing Seeded Voids

Small spheres are incorporated, then vaporized to produce the voids.

Lewis Research Center, Cleveland, Ohio

Internal and surface voids of known sizes can be incorporated into silicon carbide and silicon nitride ceramic reference specimens at prescribed locations. These specimens are used to demonstrate sensitivity and resolution in nondestructive examination techniques like scanning laser acoustic microscopy (see Figure 1) and x-radiography, and to assist in establishing proper examination procedures.

The raw material for the ceramic in a given case is silicon nitride or silicon carbide powder of appropriate purity and particle size, prepared in a manner appropriate for dry pressing and with sintering aids and binder representative of the silicon carbide or silicon nitride ceramic object to be inspected by the applicable nondestructive technique. Spheres of a solid material that vaporizes at a temperature lower than the sintering temperature of the ceramic are used to seed the voids in the ceramic; the material recommended for this purpose is styrene divinyl benzene.

The first step in fabricating a speci-

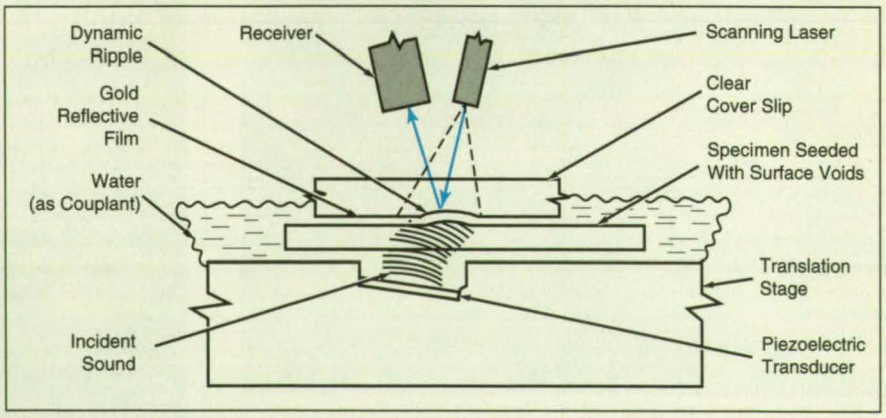


Figure 1. The **Scanning Laser Acoustic Microscope** is used to detect voids in the ceramic specimen which, in this case, is a reference specimen seeded with surface voids as described in the text.

men is to pour the ceramic powder into a die. The surface of the powder is leveled at the desired thickness, then the powder is pressed in the die at a pressure of 60 MPa. After pressing, the top surface of the powder is cleaned by a gentle stream of dry air to remove particles that are not flush with the surface. If voids embedded in the ceramic are desired, spheres to seed the voids are placed at known locations on the surface of the powder and pushed into the surface at a pressure of 60 MPa.

More powder is added to obtain the desired separation between layers of voids, and the sequence of leveling, pressing, cleaning, and pressing in of spheres is repeated. When the desired layers of spheres to form internal voids have been formed, a final layer of powder is added. If surface voids (see Figure 2) are desired, then the final layer is leveled, cleaned, and pressed at 60 MPa; the spheres to seed the voids are added as before; and the spheres are pressed into the surface at 120 MPa. If no surface voids are desired, the final surface is pressed immediately at 120 MPa, this higher pressure being necessary to strengthen the compacted powder specimen sufficiently to withstand subsequent processing without breakage.

The compacted but still unfired ("green") specimen is placed in a thin-wall latex tube, which is then evacuated and sealed. The specimen thus encapsulated is cold-isopressed at a pressure suitable for the specific material — nominally at 420 MPa. The isopressed specimen is removed from the tube, then heated in a vacuum to a temperature of 550 °C for 45 min to decompose the styrene divinyl benzene spheres. Other temperatures and heating times may be necessary for spheres made of other materials, and a slightly lower temperature can be used if the specimen is to contain surface voids only.

Finally, the specimen is sintered to achieve full densification. Silicon nitride should be sintered at a temperature of 2,140 °C for 2 h in a static nitrogen atmosphere at 5 MPa; silicon carbide should be sintered at 2,200 °C for 0.5 h in argon at 0.1 MPa.

This work formed the basis for the ASTM Standard Practice C1212-92 entitled "Fabricating Ceramic Reference Specimens Containing Seeded Voids."

This work was done by George Y. Baaklini, Stanley J. Klima, and Don J. Roth of **Lewis Research Center's** *Materials Division. For further information,* ***write in 40*** *on the TSP Request Card.*

LEW-15739

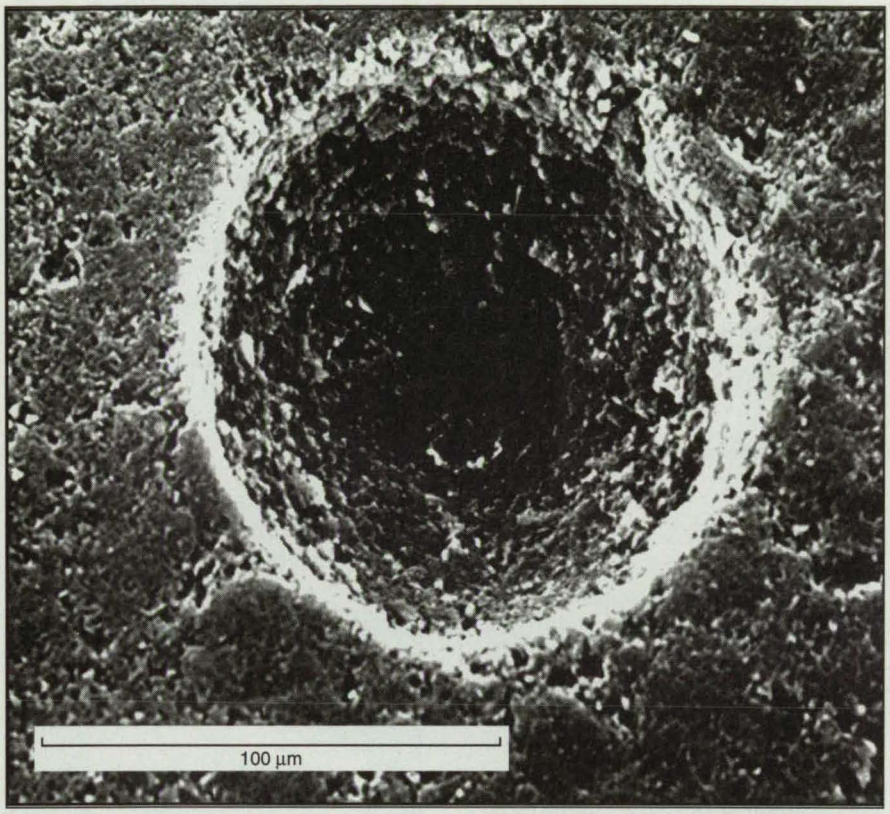


Figure 2. A **Seeded Void** in the surface of a sintered specimen is shown in this electron micrograph. Such voids tend to be ellipsoidal rather than spherical, and those in sintered silicon carbide tend to be shallower than those in sintered silicon nitride.

Using Finite-Element Analysis in Estimating Reliability

Probabilistic estimation and stress-analysis techniques are combined.

Lewis Research Center, Cleveland, Ohio

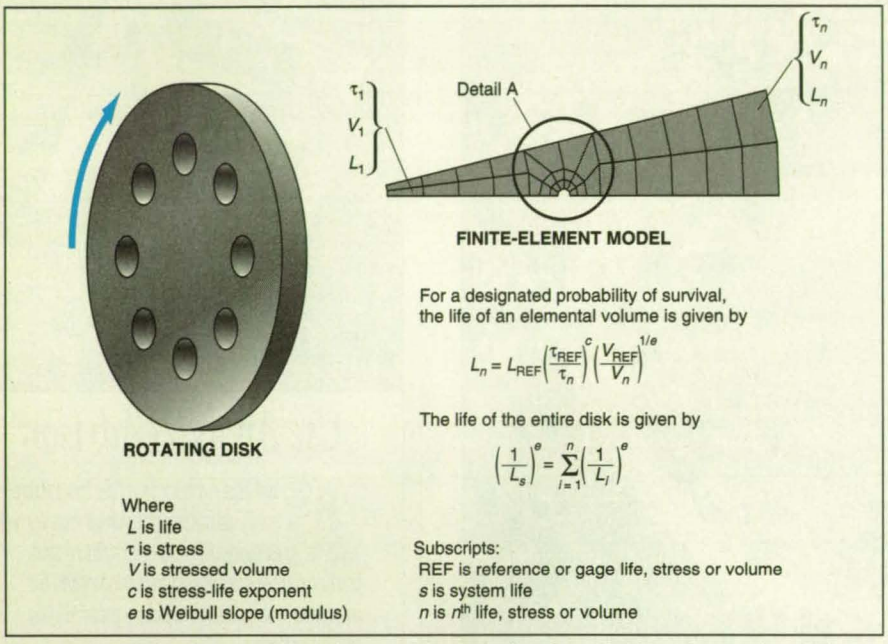


Figure 1. A **Finite-Element Model** is used in analyzing the reliability of a rotating disk that contains bolt holes.

A method of estimating the design survivability of a structural component incorporates finite-element and probabilistic properties of materials. This method involves evaluation of design parameters through direct comparisons of the survivability of the component expressed in terms of percentages of like components that survive at various lifetimes. The probabilistic properties of materials, given in terms of Weibull parameters, are coupled with the stress field computed by finite-element analysis to determine fatigue life based on initiation of cracks.

A unique advantage of this approach is that fatigue testing of a coupon of material is the only mechanical testing needed to establish the fatigue parameters necessary for analysis of the life and survivability of a full-size component made of that material. Thus, the method can be used in the early stages of a design process to optimize life-based designs, thereby reducing the amount of testing of full-sized components needed to validate the designs.

The method has been applied to a rotating disk that contains bolt holes, representative of disks used in aerospace propulsion turbines. Figure 1 shows the disk and a finite-element model of a sector of the disk (the models of the remaining sectors are identical by symmetry). The model was used in parametric computational studies of (1) the effect of the speed of rotation on the survivability of the disk and (2) the probabilistic effects of the properties of the disk material on the survivability of the disk. Figure 2 shows shear-stress and probability-of-survival contours in the vicinity of a bolt hole.

One of the advantages of the method is that it takes account of the influence of the total state of stress in a component in calculations of the survivability of the component. Another advantage lies in identification of regions within the component that are critical, with respect to survivability, for purposes of optimization. Reliability can be enhanced in regions that would otherwise exhibit low survivability, whereas weight can be reduced in regions that would otherwise exhibit high survivability.

This work was done by Erwin V. Zaretsky of **Lewis Research Center** *and Richard August of Sverdrup Technology, Inc. Further information may be found in NASA TM-104400 [N91-23550/TB], "Incorporating Finite Element Analysis Into Component Life and Reliability" and NASA TM-106022, [N93-23406/TB], "Fatigue Criterion to System Design, Life and Reliability — A Primer."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, User Services Division, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number. LEW-15864

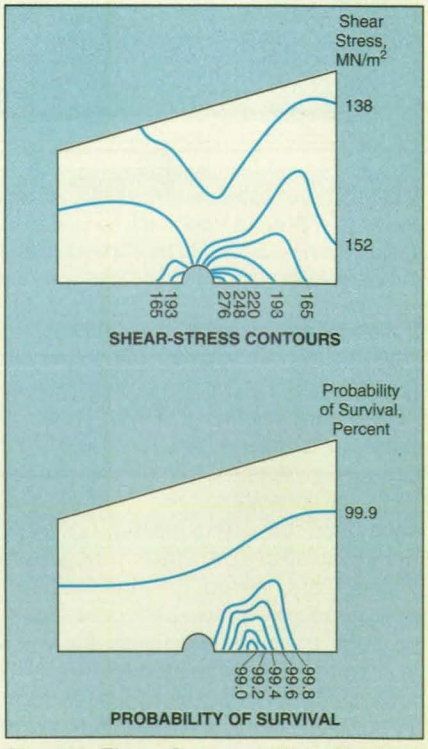


Figure 2. These **Contours Were Obtained With Finite-Element Analysis** of detail A in Figure 1. The computation was performed with L_{REF} = 10,000 cycles and a speed of rotation of 12,800 r/min. The survivability of the disk is computed as the product of survivabilities of all the finite elements.

Stereoscopic, Force-Feedback Trainer for Telerobot Operators

Operators can be trained on a simulator to prevent damage to real robots.

NASA's Jet Propulsion Laboratory, Pasadena, California

A computer-controlled simulator for training technicians to operate remote robots provides both visual and kinesthetic virtual reality. The simulator is used during the initial stage of training as a realistic substitute for a telerobot; it saves time and expense, increases operational safety, and prevents damage to robots by inexperienced operators.

The training simulator computes the virtual contact forces and torques of a compliant robot in real time, providing the operator with the feel of the forces experienced by the manipulator as well as a view of it in any of three modes: a single view, two split views, or a stereoscopic view. From a keyboard, the user can specify the force-reflection gain and the stiffness (compliance) of the manipulator hand for three translational and three rotational axes.

The system offers two simulated telerobotic tasks. One of them is insertion of a peg in a hole in three dimensions. (See figure.) As the operator performs the insertion task, the simulator continuously shows an image of both peg and hole and feeds back manipulator contact forces through a force-reflecting hand controller. The other simulated task is removal and insertion of a drawer.

The stereoscopic display is a modified commercial apparatus in which left and right views are displayed alternately on the same video screen. The operator wears liquid-crystal-shutter goggles. A signal transmitted by an infrared emitter atop the stereoscopic video display synchronizes the shutters. When the left view is displayed, only the left shutter is open (clear), and the right shutter is opaque. When the right view is displayed, only the right shutter is open. The video display is refreshed 120 times per second — frequently enough to appear not to flicker.

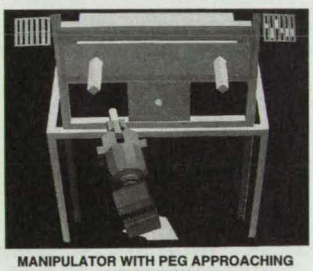
Software for the stereoscopic display generates views for the two eyes from slightly different perspectives. Both views are obtained by projecting objects in the scene onto a plane called the "zero-disparity plane," which is parallel to the plane of the display and is defined so that the points in the two images that represent the same points on the same object have the same horizontal coordinate in both images, regardless of the horizontal separation between the viewpoints (the locations of the simulated cameras). The views from the left and right viewpoints are obtained by simply translating the viewpoints right and left.

The simulator is called a "high-fidelity" system for several reasons:

- The simulation is based on accurate mathematical models of kinematics and dynamics of the manipulator and other objects.
- The display is detailed and accurate.
- Animated manipulator motions are smooth, with little or no perceptible lag between the operator's control actions and the corresponding simulated images and contact force feedback via the hand controller.

This work was done by Won S. Kim, Paul S. Schenker, and Antal K. Bejczy of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 266*** *on the TSP Request Card.*

NPO-18852



MANIPULATOR WITH PEG APPROACHING HOLE IN WALL

PEG IN CONTACT WITH WALL

MANIPULATOR INSERTING PEG IN HOLE

The **Video Display of a Simulation** shows a robotic manipulator inserting a peg in a hole.

Books & Reports

These reports, studies, and handbooks are available from NASA as Technical Support Packages (TSPs) when a Request Card number is cited; otherwise they are available from the NASA Center for Aerospace Information.

Physical Sciences

Dynamics of Ions in a Radio-Frequency Quadrupole Trap

A report describes a computer-simulation study of the motions of various numbers (up to 512) of ions in a Paul trap, which is an axisymmetric quadrupole potential well created by imposition of a combination of dc and radio-frequency electric fields. This study is part of a continuing effort to understand the motions of trapped charged particles (which can be atoms, ions, molecules, or dust particles). The motions can be characterized in terms of heating by radio-frequency fields, the formation of crystallike structures in cold clouds of trapped particles, and other phenomena that are important in the operation of radio-frequency traps in frequency standards.

This work was done by John D. Prestage, Angelyn P. Williams, and Lutfollah Maleki of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Dynamics of Charged Particles in a Paul Radio-Frequency Quadrupole Trap,"* ***write in 178*** *on the TSP Request Card.*
NPO-18633

Comparison of Measurements of Atmospheric Water Vapor

A report presents an experimental intercomparison among measurements by four spectrometric instruments for determining the concentration of atmospheric water vapor. Three of the instruments are ground-based and are needed to provide independent data to calibrate and validate the measurements taken by the fourth instrument, which is the airborne visible/infrared imaging spectrometer (AVIRIS). Heretofore, water-vapor data have been collected primarily by radiosondes carried aloft by balloons. Remote down-looking instruments like the AVIRIS can increase the accuracy and coverage of water-vapor measurements over those of radiosondes, but calibration and validation are needed. The experimental intercomparison was performed to satisfy this need.

This work was done by Carol J. Bruegge, James E. Conel, Jack S. Margolis, Robert O. Green, Geoffrey C. Toon, Veronique Carrere, Ronald G. Holm, and Gordon L. Hoover of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "In-situ water-vapor retrieval in support of AVIRIS validation,"* ***write in 205*** *on the TSP Request Card.*
NPO-18431

Materials

Reactive Melt Infiltration of Silicon Into Porous Carbon

A recent report describes a study of the synthesis of silicon carbide and related ceramics by reactive melt infiltration of silicon and silicon/molybdenum alloys into porous carbon preforms. Reactive melt infiltration has potential for making components in nearly net shape. In comparison with other processes, reactive melt infiltration can be performed in less time and at lower temperature.

Ideally, reactive melt infiltration would convert the carbon to fully dense silicon carbide. In practice, the final material may contain some free carbon and silicon or silicon alloy and may be slightly porous. The object of the study was to determine the effect of initial pore volume fraction, pore size, and infiltration material on the quality of the resultant product.

This work was done by Donald R. Behrendt of **Lewis Research Center,** *and Mrityunjay Singh of the National Research Counsel. Further information may be found in NASA TM-105860 [N93-12398/TB], "Studies of the Reactive Melt Infiltration of Silicon and Silicon-Molybdenum Alloys in Porous Carbon."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, User Services Division, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number.
LEW-15861

Making Ceramic Fibers by Chemical Vapor

Research and development of fabrication techniques for the chemical vapor deposition (CVD) of ceramic fibers are presented in two new reports. The fibers of SiC, TiB_2, TiC, B_4C, and CrB_2 are intended for use as reinforcements in metal-matrix composite materials. CVD offers important advantages over other processes: the fibers are purer and stronger and can be processed at temperatures below the melting points of the constituent materials. Fibers of the various ceramic materials were made by depositing the ceramic materials on carbon-fiber tows and, in some cases, tungsten fibers from a variety of gaseous reactants. Processing sequences, processing conditions, and materials were selected for further development on the basis of thermodynamic analyses of a wide range of precursor materials, temperatures, pressures, and concentrations. Both continuous and batch processes were investigated.

This work was done by Vithal V. S. Revankar and Vladimir Hlavacek of the State University of New York at Buffalo for **Lewis Research Center.** *To obtain copies of the reports, "Synthesis of High Performance Silicon Carbide Fibers by Chemical Vapor Deposition" and "Synthesis of High Performance Ceramic Fibers (Titanium diboride, Titanium carbide, Boron carbide) by Chemical Vapor Deposition for Advanced Metallics Reinforcing,"* ***write in 219*** *on the TSP Request Card.*
LEW-15415

Comparison of Models of Metal-Matrix Composites

A report presents a comparative review of four mathematical models of the micromechanical behaviors of fiber/metal-matrix composite materials. While the models differ in various details, all four are based on the properties of the fiber and matrix constituent materials, all involve square arrays of fibers that are continuous and parallel and all assume complete bonding between the constituents. Computer programs that implement the models are used to predict the properties and stress-vs.-strain behaviors of unidirectional- and cross-ply laminated composites made of

boron fibers in aluminum matrices and silicon carbide fibers in titanium matrices. The stresses in the fiber and matrix constituent materials are also predicted.

This work was done by C. A. Bigelow and W. S. Johnson of **Langley Research Center** *and R. A. Naik of Planning Research Corp. (Kentron). To obtain a copy of the report, "A Comparison of Various Micromechanics Models for Metal Matrix Composites,"* ***write in 214*** *on the TSP Request Card.*
LAR-14463

Mechanics

Equations for Selected Fracture-Mechanics Parameters

Equations that describe crack-mouth-opening displacements, stress-intensity factors, and related fracture-mechanics parameters of chevron-notched short bar and rod specimens are presented in a new report. The equations were developed by fitting curves to previously available data from compliance (crack opening and extension vs. load) tests of specimens from throughout the range of common specimen geometries. The equations are in forms suitable for determining fracture toughnesses from maximum loads, for determining crack-extension-resistance curves ("R-curves"), and for setting sensitivities of testing instruments. The equations will be especially useful in facilitating the testing and the interpretation of data from tests of brittle metals, ceramics, and glasses, which can be formed into chevron-notched specimens for fracture testing according to these concepts, but are difficult to fatigue-precrack to simulate natural flaws for fracture-toughness testing by older techniques.

This work was done by Raymond T. Bubsey, Thomas W. Orange, William S. Pierce, and John L. Shannon, Jr., of **Lewis Research Center.** *Further information may be found in NASA TM-83796 [N93-15369/TB], "Closed-Form Expressions for Crack-Mouth Displacements and Stress Intensity Factors for Chevron-Notched Short Bar and Short Rod Specimens Based on Experimental Compliance Measurements."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, Linthicum Heights, Maryland, Telephone No. (301) 621-0390. Rush orders may be placed for an extra fee by calling the same number.
LEW-15865

Computed Flow Through an Artificial Heart and Valve

A NASA technical memorandum discusses computations of the flow of blood through an artificial heart and through a tilting-disk artificial heart valve. The memorandum represents further progress in the research described in "Numerical Simulation of Flow Through an Artificial Heart" (ARC-12748), NASA Tech Briefs, Vol. 15, No. 12, (December, 1991), page 66. One of the purposes of this research is to exploit the advanced techniques of computational fluid dynamics and the capabilities of supercomputers to gain an understanding of complicated internal flows of viscous, essentially incompressible fluids like blood. Another purpose is to use that understanding to design better artificial hearts and valves.

This work was done by Stuart E. Rogers and Dochan Kwak of **Ames Research Center**, *Cetin Kiris of MCAT Institute, and I-Dee Chang of Stanford University. Further information may be found in NASA TM-102270 [N93-72471/TB], "Numerical Simulation of Flow Through Two Biofluid Devices."*

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ARC-12983

Computed Flow Through an Artificial Heart Valve

A report discusses computations of blood flow through a prosthetic tilting disk valve. The computational procedure developed in this simulation can be used to design better artificial hearts and valves by reducing or eliminating the following adverse flow characteristics: (1) large pressure losses, which prevent hearts from working efficiently; (2) separated and secondary flows, which can cause clotting; and (3) high turbulent shear stresses, which can damage red blood cells.

The report reiterates and expands upon part of the NASA technical memorandum described in the previous brief "Computed Flow Through an Artificial Heart and Valve" (ARC-12983). It is also based partly on the research described in "Numerical Simulation of Flow Through an Artificial Heart" (ARC-12478), NASA Tech Briefs, Vol. 15, No. 12, (December 1991), page 66.

This work was done by S. Rogers and D. Kwak of **Ames Research Center** *and C. Kiris and I. Chang of Stanford University. Further information may be found in AIAA paper A90-22243, "Numerical Simulation of the Incompressible Internal Flow Through a Tilting Disk Valve."*

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ARC-13123

Further Research on Helicopter Tail-Boom Strakes

Two documents discuss the results of additional investigations of the concept introduced in "Helicopter Tail-Boom Strakes" (LAR-13233), NASA Tech Briefs, Vol. 10, No. 2 (March/April 1986), page 132. The essence of the concept is that a strake or a pair of strakes on the side of the tail boom that faces the retreating side of the main rotor of a helicopter perturbs the flow (principally, downwash from the rotor) in such a way as to increase the aerodynamic pressure on that side, thereby contributing a force to the thrust from the tail rotor. Because of this force, the thrust required of the tail rotor for yaw control is reduced. This is an important advantage in low-speed flight, especially in sideward (toward the side opposite that of the strakes) flight, in which the tail-rotor thrust in the absence of a strake is sometimes insufficient. One of the documents is a short, untitled discussion of the concept in question-and-answer form. The other document is a report that describes an experimental study in which the effects of tail-boom strakes were investigated on an Army helicopter in flight.

This work was done by Henry L. Kelley, Cynthia A. Crowell, and Kenneth R. Yenni of **Langley Research Center** *and Michael B. Lance of Lockheed Engineering and Sciences Co. To obtain a copy of the untitled summary plus the report, "Flight Investigation of the Effect of Tail Boom Strakes on Helicopter Directional Control,"* ***writer in 285*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,209,430). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14219.

Test of Digital Image Velocimetry

A report describes an experiment to test digital image velocimetry, which Is being developed to measure velocities of flows seeded with light-reflecting particles. Digital image velocimetry has been described previously in NASA Tech Briefs. To recapitulate: The flow in question is illuminated, and a sequence of video, photographic, or holographic images of the particles are recorded at known short intervals of time. The images are digitized and enhanced. Then the average velocity during the interval between two sequential images is computed by use of correlations between the images.

This work was done by Y. C. Cho of ***Ames Research Center*** *and H. Park of the University of California, Berkeley. Further information may be found in NASA TM-102875 [N93-72467/TB] "Instantaneous Velocity Field Measurement of Objects in Coaxial Rotation Using Digital Image Velocimetry."*

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Machinery

Circular Scanning With RUM Actuators

A technical paper discusses the use of rotating-unbalanced-mass (RUM) actuators to scan scientific instruments in circular patterns centered on target points. It proposes reconfiguration of an existing experimental raster- and line-scanning RUM apparatus to enable experiments on circular scanning. It presents formulas for calculating the effects of a RUM mounted on the ends of a gimballed beam. Calculations for control gains of RUM and gimbal servos are also presented. The report describes a numerical simulation that predicts that a representative circular-scanning RUM actuator would consume 1/33 the power of an equivalent gimbal torquer in normal Earth gravity and 1/688 times the power of the gimbal torquer in zero gravity.

This work was done by M. E. Polites and D. C. Alhorn of **Marshall Space Flight Center.** *Further information may be found in NASA TP-3282 [N92-33601/TB], "Reconfiguring the RUM Experiment To Test Circular Scanning With Rotating Unbalanced-Mass Devices on Gimballed Payloads."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, User Services Division, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number. MFS-28919

Active Inertial Vibration Isolators and Dampers

A report describes the development of active inertial vibration isolators and dampers in which the actuators are electromagnet coils that move linearly within permanent magnetic fields in housings, somewhat as though they were massive, low-frequency voice coils in loudspeakers. Accelerometers detect the vibrations, and the outputs of the accelerometers are processed by digital electronic control circuits to generate currents in the coils such that the exchange of momentum between the coils and the housings gives rise to opposing vibrations and the resulting overall level of vibrations is zero or very small. The report discusses the principle of operation, electrical and mechanical considerations in the design of actuators, characteristics of accelerometers, and frequency responses of control systems. It describes the design and performance of a one- and a three-degree-of-freedom vibration-suppressing system based on this concept.

This work was done by Darren Laughlin, John Blackburn, and Dennis Smith of Applied Technology Associates for **Lewis Research Center.** *Further information may be found in NASA CR-190798 [N93-15353/TB], "Digital Active Material Processing Platform Effort (Damper), SBIR Phase II."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, Linthicum Heights, Maryland, Telephone No. (301) 621-0390. Rush orders may be placed for an extra fee by calling the same number. LEW-15872

Tests of a Magnetic Bearing for Cryogenic Applications

A report describes experiments performed in a test rig on a hybrid magnetic bearing for possible use in turbopumps at low temperature. The bearing includes a permanent magnet that provides bias magnetic flux, plus electromagnet windings, shaft-position sensors, and associated control circuitry that provide active control of position. The bearing supported a flexible rotor that served as a model of a rotor subject to bending. The rotor and bearing were placed in a test rig in which they were immersed in liquid nitrogen and driven by a motor to speeds up to 14,000 r/min. The results of the tests indicate that it is feasible to use the bearing in cryogenic environments and that the bearing damps the bending-mode vibrations of the flexible rotor as the rotor accelerates or decelerates through speeds at which bending-mode oscillations are excited. The report concludes that further work should be done on the bearing controller to increase the effective bearing stiffness, and that improved displacement sensors should be developed to reduce temperature drift and electrical noise.

This work was done by Eliseo DiRusso and Gerald V. Brown of **Lewis Research Center.** *Further information may be found in NASA TM-105627 [N92-20523/TB], "Performance Tests of a Cryogenic Hybrid Magnetic Bearing for Turbopumps."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, User Services Division, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number. LEW-15869

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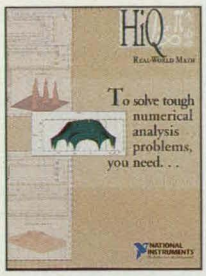

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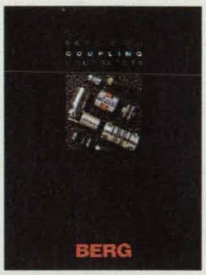

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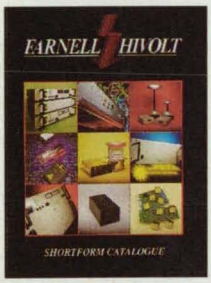

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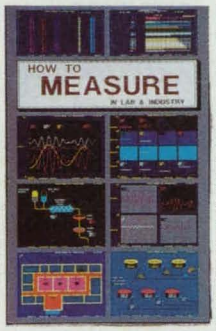

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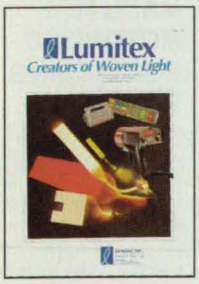

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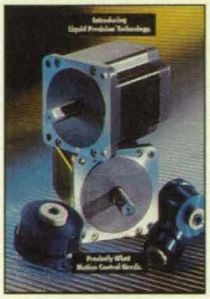

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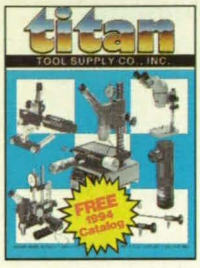

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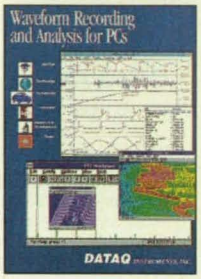

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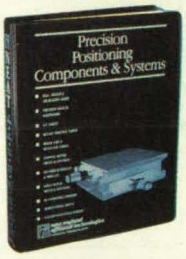

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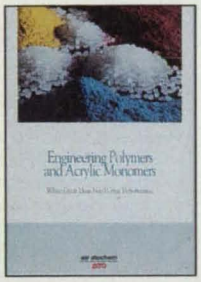

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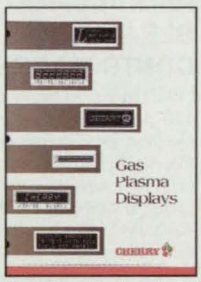

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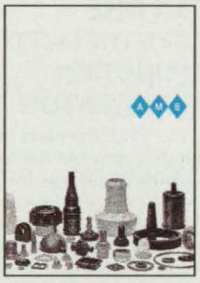

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An Elastomer Selection Guide summarizing the physical properties of the most commonly used materials in the molding, casting, extruding, and die-cut fabrication of parts is included in this package of materials from AME. Also included are data sheets on the company's line of O-Rings, switch seals (boots), self-sealing fasteners, and electrically conductive parts.

AME Corporation

For More Information Write In No. 330

TRANSMISSIVE/REFLECTIVE WORKSTATION

Increase throughput and quality levels for both color and B&W film imagery with gordon's free-standing, digitizing work console. Gordon's exclusive PLANNAR light source features: 3200 K quartz halogen lighting, ±5% flatness of field (no hot spots) and a dc power supply.

gordon instruments

Tel: 800-333-2672

For More Information Write In No. 331

NEW 1995-96 COLE-PARMER® INSTRUMENTS CATALOG

The new, free 1995-96 Cole-Parmer instruments catalog contains over 1700 full-color pages and features more than 40,000 products covering scientific instruments, equipment, and supplies. The catalog includes a detailed 40-page product index and table of contents, informative introductory pages for many of the catalog sections, "Hot Tips," and an 8-page section of late-breaking products. Contact Cole-Parmer Instrument Company—in the USA or Canada, call toll-free 1-800-323-4340.

For More Information Write In No. 332

TESTING & INSPECTION INSTRUMENTS FOR PAINT, COATINGS, ADHESIVES & PRINTING INKS

• 1200 PAGES • PAINT TESTING INSTRUMENTS • CORROSION CONTROL GAGES • COATING INSPECTION GAGES • FRICTION & WEAR TESTERS • LABORATORY INSTRUMENTS & EQUIPMENT

Packed with hundreds of new product descriptions, instructions, specification references and prices. Includes 21 new Gardner Machines for Washability, Friction and Wear Testing. Please call 1-800-762-2478.

Paul N. Gardner Company, Inc.

For More Information Write In No. 333

TECHNOLOGY INFORMATION

Electronic marketplace for finding technology partners and information about:

- Inventions
- Research
- Company Needs/Capabilities
- Technology Business News
- Commerce Business Daily

TRP funding provides subsidized access to small high technology companies and university and federal lab technology transfer offices. Address: One Westlakes, 1235 Westlakes Drive, Suite 210, Berwyn, PA 19312. Tel: 610-251-8000 or 800-529-KEDS.

Knowledge Express Data Systems, L.C.

For More Information Write In No. 334

REAL-TIME SIMULATION

The *SCRAMNet™-LX Network*, a real-time communications system based on a replicated shared-memory concept, is optimized for the high-speed transfer of data between computers that are all solving portions of the same real-time problem. Request your free catalog. Systran Corp., Tel: 513-252-5601 or 800-252-5601; Fax: 513-258-2729.

Systran Corp.

For More Information Write In No. 335

ELEMENTAL ANALYSIS

This brochure describes the MAS1000 instrument, which performs elemental analysis, depth profiling and channeling in crystals. In most cases, the analysis is nondestructive and quantitative. This brochure describes the capabilities of standard RBS analysis, PIXE, and other analytical techniques related to oxygen and hydrogen profiling. National Electrostatics Corp., 7540 Graber Road, P.O. Box 620310, Middleton, WI 53562-0310. Tel: 608-831-7600; Fax: 608-256-4103; Email: nec@well.sf.ca.us

National Electrostatics Corp.

For More Information Write In No. 336

INFRACAM PALM-SIZE INFRARED FPA CAMERA

Inframetrics ***InfraCAM*** features high resolution IR imaging, small size, low power requirements and interchangeable lenses. This 256 x 256 platinum silicide focal plane array (FPA) camera is a completely self-contained package weighing only 3 pounds complete. ***InfraCAM*** operates for two hours or more on a standard, commercially available camcorder battery. Send for our product literature. Tel: 508-670-5555; Fax: 508-667-2702.

Inframetrics Inc.

For More Information Write In No. 337

ULTRASONIC THICKNESS GAUGE

The easy to use T-Mike E is engineered to fit comfortably in the hand and designed for a wide range of measurement applications. Features include: 11 oz. with batteries; water resistant case and keypad; amber colored aircraft style display to reduce eye strain; automatic calibration with auto probe zero; and extended battery life. Stresstel Corp., 225 Technology Circle, Scotts Valley, CA 95066. Tel: 408-438-6300; Fax: 408-436-7917.

Stresstel Corp.

For More Information Write In No. 338

FILM INDICATES STRESS DISTRIBUTION

Pressurex® enables you to quickly and inexpensively determine compression magnitude and distribution between contact surfaces. Microcapsules within the film burst at specific pressure levels causing an instantaneous color change, and producing a permanent "topographical" image of pressure variation. **Pressurex®** is a valuable aid in QC and R&D for such applications as laminating presses, nip impressions, and bolted joints. Tel: 800-755-2201; Fax: 201-884-1699.

Sensor Products Inc.

For More Information Write In No. 339

3.1 MHz SYNTHESIZED FUNCTION GENERATOR

The DS335 combines the high accuracy and fine resolution (1 μHz) of direct digital synthesis at an affordable price. Sine, square, triangle, ramp and white noise waveforms are generated up to 3.1 MHz. The DS335 is also remarkably clean, with spurious components less than -65 dBc, and performs linear/log frequency sweeps as well as frequency shift keying. The computer interface option includes both GPIB (IEEE-488) and RS-232. Tel: 408-744-9040.

Stanford Research Systems

For More Information Write In No. 340

PROGRAMMABLE MOTION CONTROLLERS

FREE! New 1995 catalog is 128 pages and includes complete specifications on PC, VME, and STD bus motion controllers and packaged controllers with RS232/422. Also describes software including DLLs, DDEs, VBX controls for Visual Basic, and tools for autotuning and translating G-code, HPGL or AutoCAD files into motion. Catalog contains a 20-page technical reference describing closed-loop systems, motion programming and many example applications. Tel: 1-800-377-6329 or Fax: 1-408-746-2315.

Galil Motion Control Inc.

For More Information Write In No. 341

EMCOR FEATURES EMI/RFI ENCLOSURES FOR ALL TYPES OF REQUIREMENTS

Emcor Products offers two lines of modular enclosures to control emissions: The FCC Level Series is used in commercial and industrial requirements and the TEMPEST-style series is used when higher levels of attenuation are required. Both have been tested to MIL-STD-285 at a certified test facility. Emcor Products, 1600 4th Avenue NW, Rochester, MN 55901. Tel: 507-289-3371.

Emcor Products

For More Information Write In No. 342

10- TO 30-CHANNEL PORTABLE RECORDER

Astro-Med's new 30-channel field recorder with internal battery, built-in bright monitor, 1.44 MByte floppy disk drive, 1.2 MByte RAM per channel, and laser-quality print resolution is described in an illustrated 10-page brochure. The unit, called the Dash 10, offers a host of outstanding capabilities that make it today's most advanced portable recorder. Tel: 1-800-343-4039. Fax: 401-822-2430.

Astro-Med, Inc.

For More Information Write In No. 343

PRODUCTS FOR TOOLING AND MANUFACTURING

This FREE catalog provides information on more than 1800 components needed in tooling and manufacturing. Data covers dimensions, product photographs, prices and applications. The full line covers a wide selection of standardized tooling components for jigs and fixtures and a complete line of set-up and work clamping tools. It includes spring, ball and hand retractable plungers, nuts, bolts, washers, and knobs. Tel: 513-298-9994; Fax: 513-298-3715.

Northwestern Tools, Inc

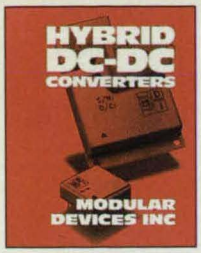
For More Information Write In No. 344

CUSTOM MOLDED FOAM

Polyethelene, EVA and Polyurethane foams, among others, can be molded to create unique OEM parts or finished products. These custom designed products are being used in medical, sports and recreation, computer peripheral and aesthetic packaging applications. Fabric, film or natural finishes available. Call for free sample card and brochure. **Flextech, Inc.**, New Hope, MN. Tel: 800-285-6660.

Flextech, Inc.

For More Information Write In No. 345



HIGH REL HYBRID DC-DC CONVERTERS

This new 32p catalog describes a full line of hybrid and discrete DC-DC converters for Space, Military and Industrial application; wide range of DC input voltages, output from 3 VDC, low output ripple, to 3 kilovolts, multiple outputs, full EMI filters/other systems type circuitry, Rad Hard versions specified, custom variations available. Tel: 1-800-333-POWR; Fax: 516-345-3106.

Modular Devices Inc.
One Roned Road • Shirley, NY 11967.

For More Information Write In No. 346

The 1994 REMCOR® Catalog describes the new line of water Chillers and Recirculators. The easy to read tables and graphs make applications and Chiller identification simple and convenient. Send for the complete Chiller Catalog today. Remcor Products Company, 500 Regency Drive, Glendale Heights, IL 60139. Tel: 708-980-6900; Fax: 708-980-8511.

Remcor Products Company

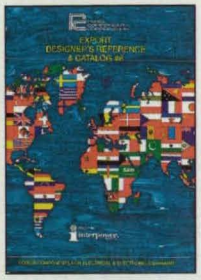
For More Information Write In No. 347

GPS-SYNCHRONIZED TIMING PRODUCTS

TrueTime's Precision Timing Products catalog features GPS-Synchronized Clocks in rackmount, portable, and board-level configurations. Includes illustrations and product specifications for our complete line of Synchronized Clocks, Time Code Products, and Remote Displays to fit a variety of time and frequency applications.

TrueTime, Inc.

For More Information Write In No. 348



INTERPOWER™ EXPORT DESIGNER'S REFERENCE CATALOG

New 224 page Reference Catalog #8 helps in designing primary power circuits of international products. Designer's Reference section shows world plug/-socket patterns, voltages and frequencies, international safety agencies and important standards published by IEC, UL and CSA. Tel: 515-673-5000; Fax: 515-673-5100.

PANEL COMPONENTS CORPORATION

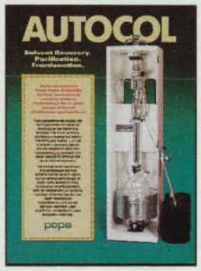
For More Information Write In No. 349

NEW MSC/NASTRAN BROCHURE

12-page brochure details latest features of leading FEA software, used worldwide to optimize and predict behavior of complex designs from aerospace and automotive to medical and consumer goods. Analysis types include static, normal modes, buckling, dynamic response, heat transfer, nonlinear, acoustic, and aeroelastic, using both h- and p-elements. Open architecture works with all modeling/CAD systems. MacNeal-Schwendler Corp., Los Angeles, CA. Tel: 800-642-7437, ext. 500.

MacNeal-Schwendler Corp.

For More Information Write In No. 350



NEW AUTOMATED DISTILLATION SYSTEM

Autocol is automated, packed column still with cost-saving applications for solvent recovery, concentration of wastes, and small scale batch production. With 15 theoretical plates for powerful fractionation of components, Autocol can automatically purify and recover individual solvents from complex mixtures. Tel: 414-251-9300; Fax: 414-251-7387.

Pope Scientific, Inc.

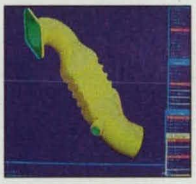
For More Information Write In No. 351

WAVE/COMPRESSION SPRINGS

Just updated, Catalog #WS-93 contains **NEW stock sizes** of wave/compression springs available from stock, including spring design formulas, materials guide and typical applications. The manual describes the many advantages of Smalley's exclusive edgewinding manufacturing process. Smalley springs, available from 3/8" to 84" in diameter, are produced by circle-coiling flat wire to exact specifications involving **no dies or special tooling charges**. Tel: 708-537-7600; Fax: 708-537-7698.

Smalley Steel Ring Co.

For More Information Write In No. 352



NON-STOP FROM PRO/E® TO ANALYSIS & OPTIMIZATION

COSMOS/M ENGINEER makes it easy and affordable to include analysis and optimization on every design itinerary. Its seamless interface to Pro/E fully integrates the design, preprocessing and postprocessing features of Pro/E with the analysis and optimization power of COSMOS/M: statics, buckling, frequency, heat transfer, optimization, nonlinear, advanced dynamics, a super fast solver and two meshing capabilities. Starting at $6500! Call 310-452-2158 (west) or 412-635-5100 (east).

COSMOS/M

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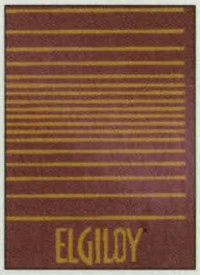


PRECISION STRIP/WIRE

Elgiloy® is a combination strip and wire mill. We process a variety of alloys including Inconel®, Hastelloy®, Monel®, MP35N®, Titanium and Stainless. Our sales and engineering staff are qualified to handle your custom material requirements, and our on site testing lab assures you of prompt deliveries. Tel: 708-695-1900; Fax: 708-695-0169.

Elgiloy® Limited Partnership

For More Information Write In No. 354

"HANDS-ON" ADVANCED COMPOSITE WORKSHOPS—SINCE 1983

The brochure describes 13 different "hands-on" workshops in advanced composite materials technology. These workshops cover fabrication, repair, manufacturing, tooling, blueprint reading, adhesive bonding, ultrasonic inspection of composites, and 4 engineering workshops. Emphasis is placed on prepreg carbon and aramid fiber materials and processes, utilizing vacuum bagging and high-temperature curing methods in the oven and autoclave. Three workshops are Canadian DOT approved. REFRESHER WORKSHOPS OFFERED. For a free brochure, call 1-800-638-8441; Fax: 702-827-6599.

Abaris Training Resources

For More Information Write In No. 355

EQUIPMENT HOUSING HARDWARE

Small quantities/immediate shipment. Design Standards offers an international selection of operational hardware for control and access of equipment and machinery. Our knobs, handles, levers, handwheels, spring plungers, levelers and wheels possess superior production, functional and aesthetic qualities. **Design Standards**: a division of Rogan Corporation, 3455 Woodhead Dr., Northbrook, IL 60062. **Tel: 800-388-5656; Fax: 708-509-1705.**

Design Standards

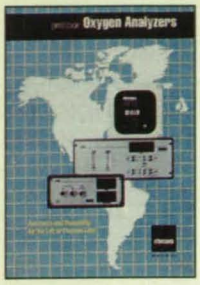
For More Information Write In No. 356

FLEXIBLE BORESCOPES

Visual inspections can be made easy with the use of a flexible borescope. Machida, Inc.'s new brochure details their complete line of quality flexible borescopes designed for various industrial inspections. Also highlighted are specialized turbine inspection kits, blending borescopes, scopes with channels and working tools, video systems, light sources and borescope accessories. Tel: 800-431-5420.

Machida, Inc.

For More Information Write In No. 357



OXYGEN ANALYZERS

A full-color brochure introduces a complete line of oxygen analyzers for the laboratory or process line. They are ideally suited for monitoring the oxygen levels in all types of gas streams. Trace oxygen levels from ppb to 100% are accurately determined by these ruggedly constructed instruments. No periodic maintenance or special operator skills are required. Intrinsically-safe and battery-operated models are also available.

Illinois Instruments Inc.

For More Information Write In No. 358

ULTRA-HARD MATERIALS FABRICATION

Insaco's brochure describes the custom manufacture of components in sapphire, ruby, quartz, ceramics of all types including glass-ceramics, alumina, zirconia, carbides, and nitrides. The company routinely fabricates these materials for applications in optics, chemistry, vacuum, bearings, electronics, nuclear, space and medicine. Tolerances are measured in millionths of an inch with surface finishes in angstroms and flatness to fractions of a wavelength. Tel: 800-959-0264; Fax: 800-959-0267.

Insaco, Inc.

For More Information Write In No. 359

MAGNETIC SHIELDING MATERIAL REFERENCE

Material guide features CO-NETIC AA alloy that shields DC to 100 kHz EMI fields. Brochure includes complete magnetic and physical data for specifications, application notes for shield design and fabrication methods. Eight page catalog MG-5 is in metric and English units and offers cross-reference to military and commercial specifications. Tel: 708-766-7800; Fax: 708-766-2813.

Magnetic Shield Corporation
Perfection Mica Company

For More Information Write In No. 360

ELECTRO-MAGNETIC DESIGN SOFTWARE

The legendary Vector Fields suite of software, including the TOSCA, ELEKTRA and OPERA packages, combines classical finite element techniques with user friendly interactive graphics for high accuracy 2D and 3D simulation and design of all types of electromagnetic equipment.

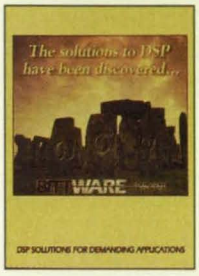
Vector Fields Inc.
1700 North Farnsworth Avenue
Aurora, IL 60505
Tel: 708-851-1734 Fax: 708-851-2106

For More Information Write In No. 309

The Capattery is a high-reliability double layer capacitor used as a standby power source in memory back-up and bridge-power applications. It has virtually unlimited cycle life and over 20x the capacitance density of conventional capacitors. With a Permselective valve, patented by Evans, 33 Eastern Ave., East Providence, RI 02914-2107, Tel: 401-434-5600; Fax: 401-434-6908.

Evans

For More Information Write In No. 361

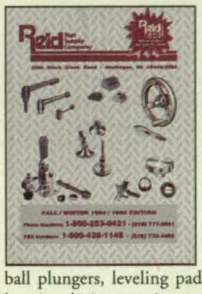


FREE DSP CATALOG

BittWare has the widest range of analog and digital I/O available for your groundbreaking DSP applications. Call us today for a catalog full of our heavy-duty ADSP 210x0-family of floating point DSP and I/O products, along with our complete set of development tools. BittWare Research Systems, 33 North Main St., Concord, NH 03301, 800-848-0436; Fax: 603-226-6667.

BittWare Research Systems

For More Information Write In No. 362

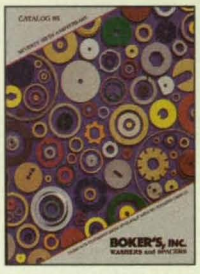


FREE CATALOG OF TOOLING COMPONENTS

New reference catalog of over 18,000 items offers a full range of tooling components and equipment. Items include handwheels, handles, knobs, spring & ball plungers, leveling pads, clamps, set up accessories, locating devices, cutting tools, springs, thread inserts, and metric items. All items are in stock for same day shipment with no minimum order requirement. Reid Tool Supply Company, 2265 Black Creek Rd., Muskegon, MI 49444. Tel: 1-800-253-1421; Fax: 1-800-438-1145.

Reid Tool Supply Company

For More Information Write In No. 363



WASHERS AND SPACERS

NEW FOR '95! Boker's free 32-page Catalog 95 offers 12,000 non-standard sizes with no tooling charges. Outside diameters of 0.080" to 2.631", a wide variety of inside diameters and thicknesses, and 2,000 material variations create millions of possibilities. Materials include low carbon, cold rolled strip and sheet steel; five types of spring steel; stainless steel; aluminum; brass; copper; nickel silver; and such nonmetallic materials as Delrin®, Teflon®, Mylar®, and nylon. Metric sizes also. Tel: 1-800-927-4377; Fax: 612-729-8910.

Boker's Inc.

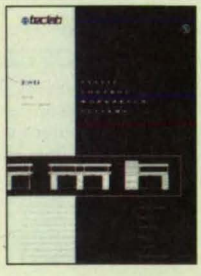
For More Information Write In No. 364

DATA ACQUISITION HARDWARE AND SOFTWARE

Strawberry Tree offers powerful, accurate and easy-to-use data acquisition hardware and software. New 1995 Catalog highlights the **DATA*shuttle*** family of portable, parallel port A/D units, our full line of plug-in boards and our **WorkBench** software for Windows, DOS and Macintosh. **Strawberry Tree**, Sunnyvale, CA. Please call **800-736-8810**.

Strawberry Tree

For More Information Write In No. 365



TECLAB ESD WORKSTATION CATALOG

Kalamazoo Technical Furniture's 8-page 4/color brochure details the Teclab line of static protective workbenches, workstation systems, and ESD controlled workstation accessories. Included are color options, product specifications, and various levels of ESD protection available. Teclab also offers a Free Planning and Design Service. Teclab, the "professional's bench." Tel: 1-800-832-5227. Fax: 616-372-6116.

Kalamazoo Technical Furniture

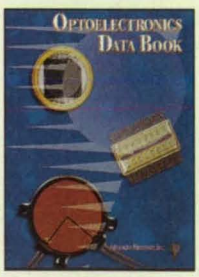
For More Information Write In No. 366

THERMOCOUPLES, MAKE YOUR OWN

The HOTSPOT allows thermocouple wire to be formed into freestanding junctions, or welded to metal surfaces. It provides a simple means of fabricating thermocouples "when needed and where needed." Brochure and specification sheet available. Address: 7300 North Crescent Blvd., Pennsauken, NJ 08110. Tel: 609-662-7272; Fax: 609-662-7862.

DCC Corp.

For More Information Write In No. 367



OPTOELECTRONICS DATABOOK

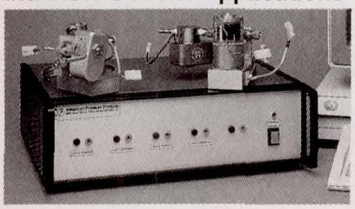
The new Optoelectronics Databook from Advanced Photonix features data on a wide range of products and capabilities. Included are over 28 pages of new products and expanded lines, such as Linear Arrays, Filter Detectors, High Speed Photodiodes and Detector Hybrids. Also highlighted is a Die Library to address application specific OEM requirements. 1240 Avenida Acaso, Camarillo, CA 93012. Tel: 805-987-0146; Fax: 805-484-9935.

Advanced Photonix Inc.

For More Information Write In No. 368

TOLL FREE ASSISTANCE FOR YOUR PRESSURE AND FLOW CONTROL NEEDS

APP Servo Valve Controller
Automate Your Custom Pressure And Flow Control Applications



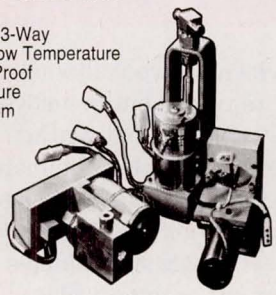
Features:

- Compact, easy to install and operate
- Completely electric operation
- Vacuum to 60,000 PSI
- Easy to retrofit in place of other valves
- Single and Multiple valve controllers
- High Temperature version available
- Explosion-proof version available
  Available in: Analog control, Self-contained digital control, or PC-based computer control
- *Custom control systems available*

Write in No. 390

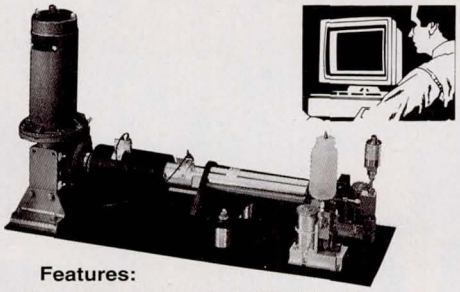
APP Valves are available in a wide variety of sizes and styles

- 2-Way and 3-Way
- High and Low Temperature
- Explosion Proof
- High Pressure
- High Vacuum
- Metering
- On-Off



Write in No. 391

Automated Pressure Control System
Automate Your Custom High Pressure Applications



Features:

- Generates pressures up to 60,000 PSI
- Uses a variety of pressurizing fluids
- Can do multiple-slope pressure-ramps
- Automatic fluid refill for large volumes
- Full manual-override control
- Multiple generator systems available for *continuous flow or multiple axes*
- Multiple pressure-outlet ports available
- Windows-based control software
- Internal torque limits
- Explosion-proof version available
- Custom control software available

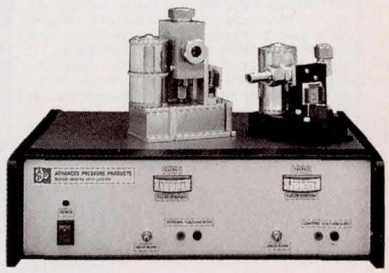
Write in No. 392

APP Corporate Philosophy

At Advanced Pressure Products we take pride in helping our customers Solve Problems. We sell Solutions, not just valves and pressure generators. We take the time to listen, analyze the problem, and then help you with the most Appropriate solution. On this page is a sampling of some of our capabilities. Please feel free to call us toll free and experience the APP Advantage for yourself.

Write in No. 393

APP Position Controlled Valves
Automate Your Custom Gas And Fluid Metering Applications



Features:

- Your analog voltage is quickly translated into position of the metering valve
- Allows easy remote control
- Compact, easy to install and operate
- Completely electric operation
- Vacuum to 60,000 PSI
- Easy to retrofit in place of other valves
- Single and Multiple valve controllers
- High Temperature version available
- Explosion-proof version available
- Cost-effective valve-automation from your existing D/A output board

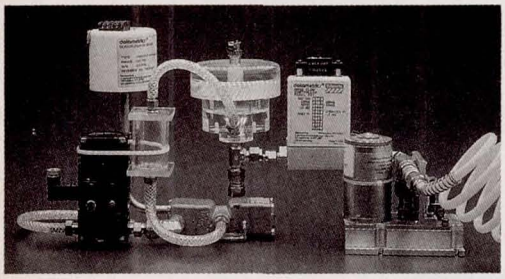
Write in No. 394

APP Automated Pressure Gauge Testing And Calibration System
Automate Your Pressure Gauge Testing and Calibration

Features:

- Generates pressures up to 60,000 PSI
- Uses a variety of pressurizing fluids
- Can do multiple-slope pressure-ramps
- Automatic fluid refill for large volumes
- Full manual-override control
- Multiple generator systems available for continuous flow or multiple axes
- Multiple pressure-outlet ports available
- Windows-based control software
- Internal torque limits
- Explosion-proof version available
- Custom control software available

Write in No. 396



APP Custom Control Systems
A Complete Solution To Your Flow And Pressure Control Needs

Features:

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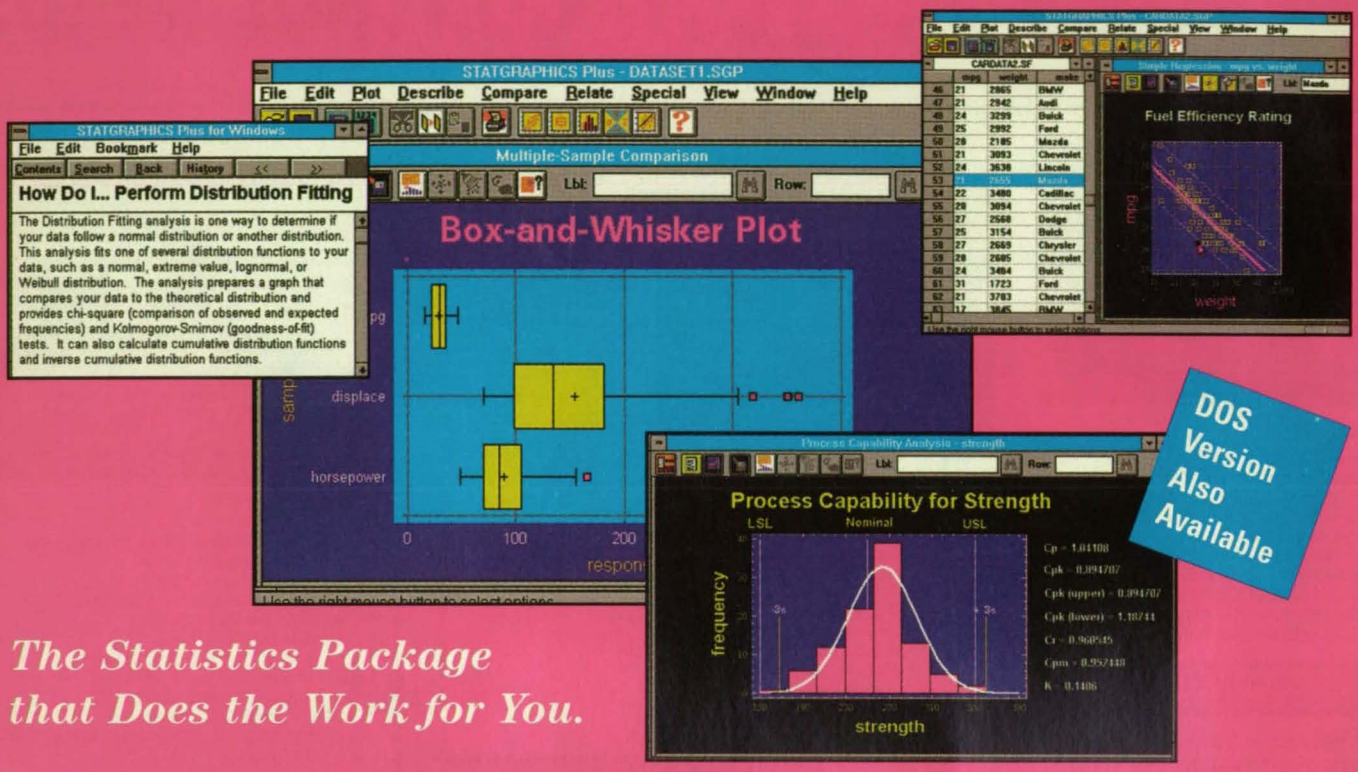

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For More Information Write In No. 506

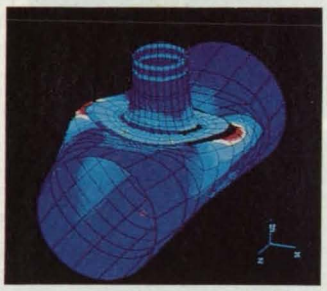
New on the Market

The ET-DSO family of low-cost, high-performance, PC-based **digital storage oscilloscopes** (DSOs) from Emulation Technology Inc., Santa Clara, CA, can isolate analog events at any time interval. The DSOs provide plug-and-play operation in PC environments and bandwidths ranging from 20-100 MHz in two- or four-channel configurations. Features include PC-based analysis of the DSO data, extensive triggering capabilities, and portability.
For More Information Write In No. 708

The PhoneDucer, 1-420 **current loop monitor** from Elwood Corp., Oak Creek, WI, measures the current level in 4-20 mA loops via internal modem over standard phone lines. Requiring no AC power or batteries, the unit includes signal conditioning and measurement circuitry with temperature compensation. Designed to poll remote instruments, it measures current to an accuracy of 0.1% Full Span with 0.01 milliamp resolution.
For More Information Write In No. 703

A novel **mechanized socket wrench** from Dynamic Aerospace Tools Co., Boulder, CO, fits directly onto any hex nut from any angle and regardless of its position. The time-saving tool employs a set of high-grade steel clutches to lock onto a hex tube nut during torque operations and then instantly release it to allow removal of the tool from the tubing. Operation requires only fitting the socket on the nut and pressing a button—the tool automatically resets to a preselected value for the next installation.
For More Information Write In No. 714

SimplyVoice for DOS, **voice recognition software** that provides command and control via voice for all popular software applications, is available from Interactive Products Inc., Eugene, OR. The package operates as a highly reliable, speaker-dependent, word (or short phrase) isolated system requiring just one training pass per command. It can contain up to 150 words in an active vocabulary while hundreds of additional vocabularies can be "swapped in" by voice command.
For More Information Write In No. 713



Finite element analysis (FEA) software for piping and vessel engineers has been released by COADE Engineering Software Inc., Houston, TX. The easy-to-use FE/Pipe is designed to eliminate errors associated with current pipe engineering methods such as WRC 107, WRC 297, and hand calculations. Priced under $4000, the program enables engineers with no prior FEA experience to generate results in less than day.
For More Information Write In No. 711

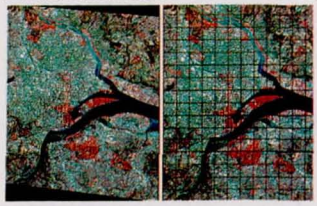
Aromat Corp., New Providence, NJ, has announced the Soft-ON/OFF **photoMOS relay** combining features of electromechanical relays and solid-state relays, as well as relay-protection circuits known as "arc suppressors" and "snubbers." Internal enhancements to the company's standard photoMOS relay MOSFET circuitry extends relay rise and fall times, thereby "clamping" the transients and preventing possible damage to the relay or surrounding circuit components.
For More Information Write In No. 718

Two new **greases** from Planned Products, Santa Cruz, CA, combine silver or carbon with chemically inert, thermally stable, and nonflammable silicone lubricants to protect assemblies from wear and environmental hazard while providing electrical and thermal conductivity. Both formulations cling at high operating temperatures and can be applied to seals, O-rings, gears, bearings, spines and lead screws. The silver grease can be used on substation switches, circuit breakers, and knifeblade switches.
For More Information Write In No. 701

New on the Market

Autometric Inc., Alexandria, VA, has released WarpIt™ software to speed the **geometric transformation of images** and other 2D data arrays. WarpIt is a C-callable subroutine library employing a highly optimized Nth-order polynomial warp. It allows the user to apply first order transformations such as rotate, scale, and translate, as well as higher order warps to introduce curves.

For More Information Write In No. 710



A **removable mass storage system** the size of a matchbook has been announced by SunDisk Corp., Burlingame, CA. CompactFlash™ is the first product to employ SunDisk's 32 Mbit flash technology and single chip ATA controller. Weighing just half an ounce and operating on a single supply voltage of 3.3 or 5 V, the system provides full PCMCIA-ATA functionality, yet is one-fourth the volume of standard PCMCIA Type II cards (36 X 43 X 3.3 mm).

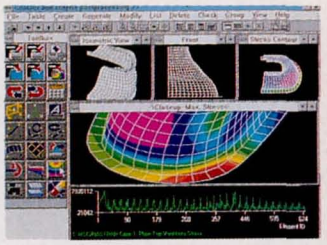
For More Information Write In No. 717

EG&G Flow Technology, Phoenix, AZ, has introduced the Smartflo™ Series of **turbine flowmeters** for mass or volumetric liquid flow measurement applications requiring accuracy, wide flow ranges, and fast response. Smartflo features integrally-mounted, microprocessor-based "smart" electronics that perform all temperature compensation functions internally to improve the meter's range and accuracy.

For More Information Write In No. 707

Elgar Corp., San Diego, CA, has introduced the SmartWave™ **AC power source** that delivers 5250 VA with a power density of 1.35 VA/in³ for ATE and power line disturbance simulation. The unit provides three independent arbitrary waveform generators and transformerless and direct-coupled amplifiers to permit users to create, edit, and generate complex waveforms with high DC content. The SmartWave also can create phase-controlled sub-cycle or multi-cycle drop-outs, spikes, sags, surges, and frequency excursions.

For More Information Write In No. 719



The MacNeal-Schwendler Corp., Los Angeles, CA, has released a Windows version of MSC/NASTRAN, its **finite element analysis software** with integrated modeling and postprocessing. It includes statics, normal modes, and buckling analysis. Graphics features include dynamic rotation, contour and X-Y plots, and beam diagrams. Modeling features include automatic and mapped meshing, material and element property libraries, and CAD interfaces.

For More Information Write In No. 712

The MK2000 **DC-DC converter** from Interpoint Corp., Redmond, WA, provides 80 W/in³ of usable power. Designed to eliminate or reduce the need for external components, the device offers up to 200 W of output power in an industry standard half-sized case (2.4 X 2.28 X 0.45 in). Its innovative design employs internal filter networks for stable operation of all rated loading conditions with no external capacitors. Low noise level eliminates the need for external filters while operating efficiencies up to 90% reduce heat sink requirements.

For More Information Write In No. 720

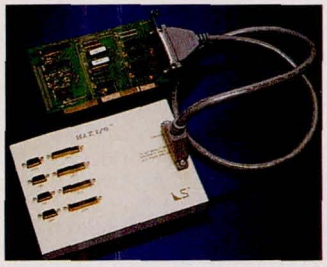
A **direct drive rotary table** introduced by New England Affiliated Technologies, Lawrence, MA, features speeds from less than 1 °/sec to 1,000 °/sec, load capacity of 500 lb. axial and 100 ft-lb torsional, ±0.001° repeatability, ±0.005° accuracy, and unlimited rotation. A crossed roller bearing supports high loads while minimizing vertical and radial runout. Direct mounting of the motor rotor to the user's mounting surface maximizes the unit's high output torque capabilities and increases velocities and accelerations.

For More Information Write In No. 704

New on the Market

The new VideoTherm 88 portable **infrared imaging system** from ISI Group Inc., Albuquerque, NM, uses Stationary Image Display technology to permit fixed viewing of an object without panning. With its AC power supply, the lightweight camera is readily transportable, virtually maintenance free, and can be operated continuously. Its high-resolution image is enhanced using a redesigned video amplifier and operator-selected recursive filters that improve the signal-to-noise ratio.

For More Information Write In No. 709



The MAX I/O™, a **network port server card** from Computer Modules Inc., Santa Clara, CA, features four 16550-compatible serial ports and four parallel ports on a single ISA slot (all ports can share one interrupt) and software drivers compatible with DOS, Windows, or Novell. Designed to improve connectivity for Pentium-based multiuser computing systems, the card offers flexible addressing options for both serial and parallel ports.

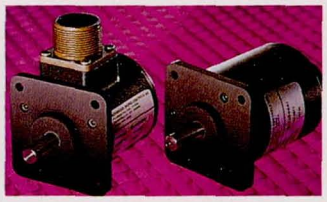
For More Information Write In No. 700

A **wiring system** from Lutze Inc., Charlotte, NC, offers a 35% reduction in cabinet space and up to an 80% decrease in assembly time. The LSC™ system replaces the basic back panel with an aluminum frame comprising mounting rails, support rails, and mounting brackets. Assembled like a kit, the frame integrates wire management and eliminates wire-ways. The design allows heat to be dispersed away from the components, gives wires the space to hang loose inside the mounting brackets, and permits access to trace and remove wires for inspection and replacement.

For More Information Write In No. 702

A **two-terminal solid-state switch** from Smith Research & Technology Inc., Colorado Springs, CO, closes when alternating current through a hole in the case exceeds a preset value. Controlling either AC or DC loads without external power, the switch functions from below 10 Hz to high audio, with sensitivity increasing with frequency. Contact chatter is prevented by internal hysteresis.

For More Information Write In No. 705



Advanced Micro Controls Inc., Terryville, CT, has introduced the DuraCoder®, a user-programmable **resolver-based encoder** that can serve as a direct replacement for incremental or absolute optical encoders in industrial applications. The device is plug-compatible with standard connections to facitilate field replacement and can produce outputs in either 1-20 mA analog voltage or in digital pulses for computer-based interfaces.

For More Information Write In No. 715

Yaskawa Electric America Inc., Northbrook, IL, has unveiled the PROGIC-8, a compact multiaxis **motion controller** that integrates motion and sequence control. The PROGIC-8 controls up to eight axes and features a built-in programmable logic controller (PLC) for auxiliary sequencing. Sequence programs for the PLC, motion programs, and control parameters can be loaded, edited, and saved on a PC or laptop.

For More Information Write In No. 706

SCM Products Inc., Islandia, NY, has released the Keyboard/Mouse Quad Switch, a **PC add-on that allows users to control up to four PCs with just one keyboard and mouse.** The switch features internal memory and intelligence so that programs may run undisturbed while switching from one PC to another. It retains several keyboard LED settings (cap-, scroll-, and number-lock) for each PC, and interfaces to any standard keyboard input.

For More Information Write In No. 716

New Literature

A guide to **temperature and liquid level probes for cryogenic applications** has been published by Scientific Instruments Inc., West Palm Beach, FL. The field-tested probes feature rugged assemblies, quick time response, intrinsic safety, and multimedia use.

For More Information Write In No. 721

Products designed to make **video technology** easier to capture, transfer, and manage are described in literature from Toshiba Video Communications and Information Systems, Buffalo Grove, IL. Entitled "Image Transfer Technology," the guide features microminiature cameras, high-performance monitors, studio-quality VCRs, and high-resolution printers. An easy-to-read product selection chart also is provided.

For More Information Write In No. 724

A new **plastic coupling** for extreme temperatures is described in a brochure from Colder Products Company, St. Paul, MN. The HGC-35 quick disconnect couplings, made from plastic polysulfone resin, can handle temperatures from -40 to 138 °C, repeated autoclaving, boiling water, strong oxidants such as bleach, and other chemicals. They are available in panel mount, in line, elbow, and pipe thread configurations to fit 3/8", 1/2", and 3/4" hose barbs.

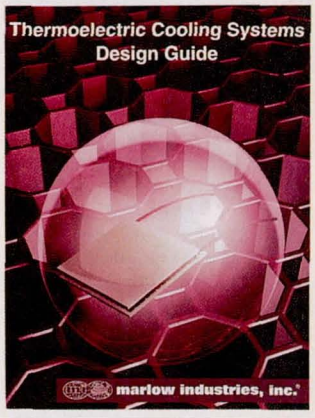
For More Information Write In No. 723

A 120-page catalog from De-Sta-Co, Troy, MI, provides technical information on a wide range of **clamps**. Featured products include new heavy-duty toggle clamps, Toggle Lock Plus clamps, and hydraulic devices. The publication illustrates vertical and horizontal hold-down action clamps and straight-line, latch, and squeeze action clamps.

For More Information Write In No. 722

A **thermoelectric cooling systems** design guide has been published by Marlow Industries Inc., Dallas, TX. The 20-page booklet addresses thermoelectric theory, estimating heat loads, selecting one- or two-stage thermoelectric coolers, power supply requirements, and mounting methods. Applications include infrared detectors, air-to-air exchangers, charge-coupled devices, liquid exchangers, and high-speed integrated circuits.

For More Information Write In No. 726



FutureVision, Buchanan, GA, has published ***Space Industrialization: A Guide to Government Information***, a booklet listing 439 related documents issued by the US government since the late 1970s. Subjects include launch vehicles and services, remote sensing, commercial space policy, space nuclear power, and the activities of foreign space programs.

For More Information Write In No. 725

Miles' Polymers Division, Pittsburgh, PA, has released a brochure detailing the uses and benefits of Texin and Desmopan **thermoplastic polyurethanes**, which bridge the gap between rubber and plastic. The materials provide the processing efficiencies typical of thermoplastics, whether injection molded, extruded, or blow-molded. Performance benefits include high abrasion resistance and tensile strength, flexibility over a wide temperature range, and elasticity over the entire hardness range.

For More Information Write In No. 727

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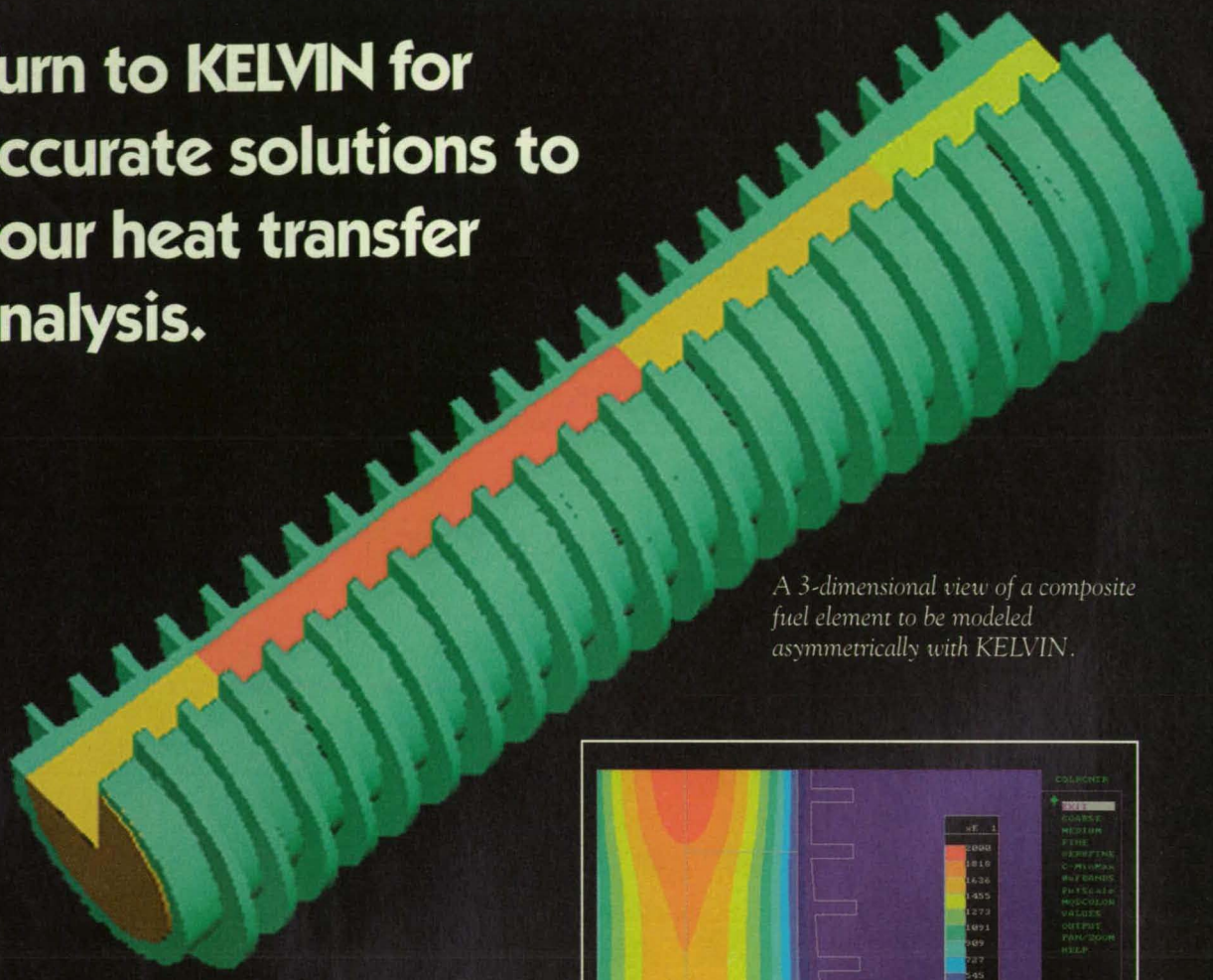

A 3-dimensional view of a composite fuel element to be modeled asymmetrically with KELVIN.

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For More Information Write In No. 653

continued from page 14

CLIPS: A "Clip-On" Expert Systems Program

If limitations (in a slight variation on the adage) are the parents of invention, then NASA's computing conditions provided ground for innovation. Gary Riley, a computer engineer in the Software Technology Branch at NASA's Johnson Space Center, said that NASA computer hardware, because of the lengthy flight certification process, often was "not up to date." In the early 1980s, when NASA Johnson needed to build complex expert systems to solve problems that required human-like expertise, "We had computers that were not supported by the vendors anymore, so we couldn't expect them to develop programs that required complex interfaces," Riley said. So his team was forced to devise its own solution—the C-Language Integrated Production System (CLIPS).

Understanding CLIPS and its success lies in understanding how it solved or circumvented a number of problems NASA and other organizations faced at the time it was devised. One limitation for Riley was the cost of high-end, expert-system software, which could run $40,000-50,000, with long-term licensing fees.

Another problem was that, in the early 1980s, LISP was the language of expert systems but was not appropriate for NASA. According to Riley, LISP has a "garbage-collecting" feature that automatically begins processing in the middle of program operation. Although this feature is convenient for accounting for material in your system, "it can be trouble if you're in the middle of monitoring an engine when it comes on," he said.

So Riley's team set about writing their expert system interface program in C—the most common language in the scientific community. They wrote the program to be integrated into various applications environments, and to achieve portability they developed the "portable kernel" concept. "The basic core of CLIPS," Riley said, "is set up like a DOS prompt that will work on any machine—PC, Mac, or the Cray supercomputer." To increase versatility, CLIPS has access functions that allow it to be embedded within other programs so that an expert system can be called up as a subroutine, or other information in CLIPS can be accessed. Innovative at the time, this feature has since been integrated throughout the industry.

A unique feature of CLIPS is the availability of its source code, enabling other programmers to use the program as a foundation to build up their own functionalities. "This makes it easy to add other things to the program—several companies have made modifications to it and sold it as a product," Riley said. "It's become a resource."

CLIPS has been used extensively both within and outside NASA. Riley's branch at Johnson has used it to monitor systems that read and comment on telemetry data. That center also employed it in Intelligent Computer Training for flight controllers.

Other applications include a dairy herd management program that analyzes milk production at various dairies. The CLIPS part of the program draws up recommendations for the user—perhaps to provide a clean, dry environment for the udders, limit fly population, or provide more ventilation. Further, Excellerator II, from INTERSOLV, Inc., employs CLIPS in its planning, analysis, and design program that helps organizations foster a manageable, predictable, and repeatable development process building on current strengths. And MathSoft Inc. used it in SmartMath, which provides an intelligent interface between the user's problem and the company's Mathcad technical calculation program. SmartMath reviews the user input and devises a problem-solving strategy by writing a new set of Mathcad equations.❑

For more information about the technologies described above, contact the technology transfer officer at the NASA Field Center that sponsored the research (see page 20).

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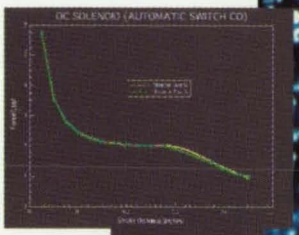

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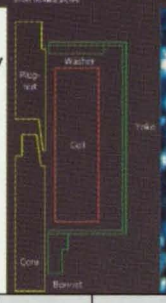

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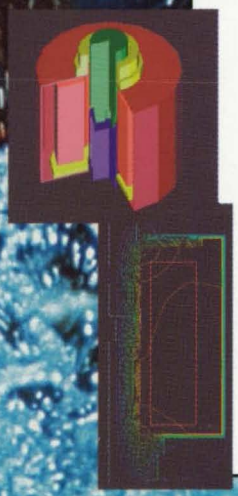
0.253	0.09080784	0.630972	15.8301
0.278	0.0917353	0.551074	12.4962
0.303	0.0869854	0.566156	10.9343
0.328	0.0833859	0.704584	10.1044
0.353	0.0801771	0.594178	9.54882
0.378	0.0774072	0.675732	9.21645
0.403	0.0748866	0.586839	9.00972
0.428	0.0726882	0.626687	8.92038
0.453	0.0706936	0.544622	8.92778



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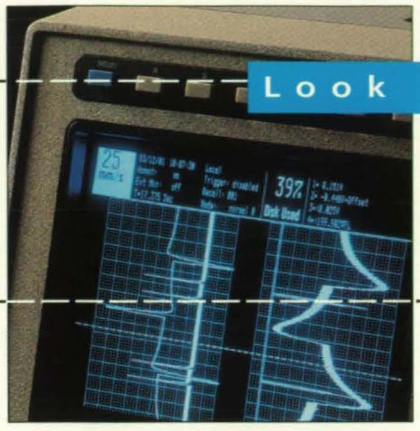
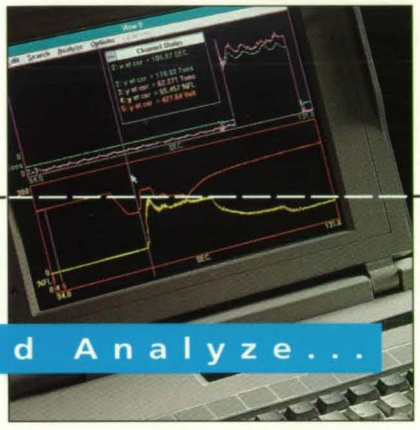
If you want to. . .

Look Later. . .



Look Now. . .



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